1987 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

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SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

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CONTENTS

WITNESSES

Page

February 20, 1986:

Dr. Roland W. Schmitt, Chairman, National Science Board 4
Erich Bloch, Director, National Science Foundation 12

February 25, 1986:

Panel I: Dr. David A. Hamburg, chairman, board of directors, American Association for the Advancement of Science; Dr. Robert M. Rosenzweig, president, Association of American Universities; and Dr. Robert W. Krauss, executive director, Federation of American Societies for Experimental Biology 91
Panel II: Dr. Clifford J. Murino, president, University Corp. for Atmospheric Research, Dr. D. James Baker, president, Joint Oceanographic Institutions, Inc., Dr. Robert E. Hughes, president, Associated Universities, Inc., and Dr. John M. Teem, president, Association of Universities for Research in Astronomy, Inc 157

February 26, 1986:

Panel I: Dr. Jon Fuller, president, Great Lakes College Association 322
Dr. Andreas A. Paloumpis, president, Hillsborough Community College, Tampa, FL 337
Joel N. Bloom, director, Benjamin Franklin Institute, Philadelphia, PA 347
Panel II: Dr. W. Dale Compton, senior fellow, National Academy of Engineering 377
Dr. Harry B. Gray, Arnold O. Beckman, professor of chemistry, Department of Chemistry, California Institute of Technology 388
Dr. Neil J. Smelser, professor, Department of Sociology, University of California at Berkeley 450
Dr. Thomas F. Malone, director emeritus, Holcomb Research Institute, Butler University 475
Dr Edward E. David, Jr., president, EED, Inc 490

APPENDICES

Appendix I: Followup questions and answers from the National Science Foundation 515

Appendix II: Statements for the record:

American Chemical Society 535
American Psychological Association 538
American Society of Mechanical Engineers 546
Chesapeake College, Wye Mills, MD 572
Children's Television Workshop 578
Colorado State University 585
Consortium of Social Science Associations 591
Federation of Behavioral, Psychological & Cognitive Sciences 600
Great Lakes Colleges Association 607
Mathematical Association of America 609
National Association of Public Television Stations 647
National Society of Professional Engineers: Engineering Education Task Force 651
Society of American Archaeology 671

1987 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

THURSDAY, FEBRUARY 20, 1986

House of Representatives,
Committee on Science and Technology,
Subcommittee on Science, Research and Technology,
Washington, DC.

The subcommittee met, pursuant to notice, at 10:05 a.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Mr. Walgren. Let me call us to order, and welcome all of you to our hearing this morning. We meet for the first time for the first of three hearings on the National Science Foundation's authorization for fiscal year 1987 this morning. I certainly want to welcome Erich Bloch, the Foundation's Director, Dr. John Moore, and Dr. Roland Schmitt, the Chairman of the National Science Board. Dr. Moore, as you know, is the Deputy Director for the National Science Foundation, and Dr. Schmitt is, as I said, the Chairman of the National Science Board.

Last year, during the budget review process, we were just getting acquainted, particularly with Mr. Bloch. We certainly have appreciated the working relationship that you have developed both formally and informally with all the members of the committee. We are glad to have your colleagues here with you today.

We consider this morning's hearing a very important one, and for that reason Mr. Boehlert and I have taken the liberty of inviting the other members of the full committee to join us. We have with us the ranking minority member, Mr. Lujan, and the chairman of the full committee, Mr. Fuqua. My apologies for others, the House being in a pro forma status today has taken many Members back to their districts.

As you know, the Foundation's fiscal year 1987 budget shows an increase of 8 percent, and includes a number of new initiatives for further growth in areas including the engineering research centers, the advanced scientific computing capabilities, biotechnology, global geosciences, and science and engineering education at all levels.

We feel that this hearing will afford committee members the opportunity to discuss with the Director and Dr. Schmitt and the Deputy Director the activities and the budget of what is the central agency in the Federal Government that we rely on for the health of American science and basic research in particular.

I'd like to mention briefly that the subcommittee's remaining 2 days of hearings on the NSF budget and its programs will be on February 25 and 26, when we will hear witnesses outside the Federal sector, including those representing scientific and professional societies, university representatives, those involved in managing the national research centers, those involved in the National Science Foundation's education programs, several involved with other areas of science education, community colleges, liberal arts colleges, and panels from various scientific disciplines such as chemistry and mathematics and engineering. So you all have a real invitation to join us for those hearings as well.

With that for an opening comment, let me turn to my own ranking minority member, Mr. Boehlert, for any opening thoughts he'd like to share with us.

Mr. BOEHLERT. Thank you very much, Mr. Chairman. As we all know, this is a crucial year in the never-ending battle of the budget. The priorities we set this year will very likely determine the shape of the budget for the entire Gramm-Rudman period. So it's vital that we make the proper decisions now.

In proposing an 8.4-percent increase for the National Science Foundation, the President made a correct decision, one that recognizes the paramount importance of NSF in preparing the United States for the future. We may, of course, in the give and take of the budget process, end up with a figure that differs somewhat from the President's proposal. But I don't think we have any cause to differ with the priority he has granted NSF.

Look at some of the most serious problems our Nation faces; growing foreign competition, record trade deficits, a large number of displaced workers, a faltering educational system. NSF has a major role to play in solving these pressing problems.

The basic research that NSF finances at our colleges and universities—research unlikely to be paid for by any other source—is our single best hope for keeping our Nation's technological edge. NSF's work promises us not only better living through chemistry, as the old ad said, but also better living through engineering, computer science, biology, social science, and numerous other fields.

NSF's education programs are designed to improve schooling at every level, from elementary school to post-doctoral work. What could be more important to our Nation's future?

Just 3 years ago, it seemed that reports were being issued daily warning of a rising tide of mediocrity in our Nation's schools. Discussion of the subject has subsided, but the concern is still very much with us.

The recently released report, "Science Indicators," notes, for example, that American students take only one-third to one-half as much high school science as do their counterparts in Japan, West Germany, and the Soviet Union. NSF has the tools to help reverse that dangerous situation.

The National Science Foundation may be little known among the general public, but the entire population benefits from its work. I think we should feel about NSF the way Daniel Webster said he felt about Dartmouth; it is a small agency, but there are those of us who love it.

Mr. **Walgren**. That's super. Let me recognize the chairman of the full committee, Mr. Fuqua.

Mr. **Fuqua**. Well, thank you, Mr. Chairman. I will also add my words of welcome to the three distinguished gentlemen who are before us today, and commend the National Science Foundation for the fine job they've done. I think the direction that it's been moving in in the last few years, and it's certainly no small credit goes to the Director, Mr. Bloch, and also to the support that he has received from the Science Board, headed by Dr Schmitt.

So, it's a great pleasure to be here. We realize under the Hollings-Rudman-Gramm proposal that we are called upon to make some very difficult decisions. This budget being a modest increase over last year puts an even greater pressure on us to make sure that the decisions that we make in this committee, and in the subcommittee, are the correct decisions.

So, we will be discussing that in detail in the course of the hearing today and those that the chairman would be pursuing in the coming weeks. So we want to thank you all for being here. We all recognize, I think, the importance of the valuable work that's conducted by the Foundation.

Thank you for your presence here this morning.

Mr. **Walgren**. Thank you, Mr. Fuqua. Mr. Lujan.

Mr. **Lujan**. Thank you very much, Mr. Chairman. I'd just like to add my welcome to our distinguished guests. I think we've got a pretty good budget to work with, one that I, as an individual member of this committee, can support. The only caution that I would raise, in visiting with some of the members of the Budget Committee, one of the things they always say; well, we'll pursue that in questioning. Well, sure it's easy for you to support the budget because in most of the areas of research you have an increase; that's true. We have what I consider a very enlightened judgment by the administration in supporting those programs.

But they're always looking—at least the Budget Committee—to make up the legislative budget as saying, well, where can we cut? We've got to be careful because that's one area that if there is a cut, we'll never know what the consequences are, they're so far out in the future when we talk about basic research, that we can seriously damage ourselves and not even know it.

So we may have to—although that's not my intention—we may have to look to you to say, to tell us, you know, if they do come to us and say where can you cut, I know that it's very difficult to say that. But I'm sure that that question is going to come up from the Budget Committee and we better at least have some priorities. Some of us feel that we will try to preserve what we have, but those are questions that are going to have to be answered.

Thank you very much, Mr. Chairman, and I look forward to the testimony of the witnesses.

Mr. **Walgren**. Thank you, Mr. Lujan. Mr. Valentine.

Mr. **Valentine**. Mr. Chairman, I don't have any opening statement to make. I just would like to say that I'll—in this time of plenty, I'll look forward to the pearls of wisdom that will be presented to us here by these gentlemen.

Mr. **Walgren**. Thank you.

Mr. **Walgren**. Well, with that, welcome to the committee. Our normal admonitions that written statements will be made part of the record, and feel free to raise the points you'd like to in whatever way you would like to and feel is most effective in making the points you'd like to make.

We're also very open to later written submissions as well. You can know that if there is a point that you would like to elaborate on that somehow gets missed, we welcome that and look forward to that.

So with that, let's turn first to Director Bloch, and then following that we'll go without intervention to Dr. Schmitt and then come back for discussion.

Mr. **Bloch**. Thank you, Mr. Chairman, and members of the committee, and Mr. Fuqua and Mr. Lujan in particular for attending this particular session. We appreciate the opportunity to discuss the 1987 budget, and I also appreciate the opportunity of having had a very good working relationship with both the members of this committee and the staff. We want to thank you for the support that you gave us last year and commend you and your colleagues in the Senate for an authorization bill after many years. It was very helpful, and I hope we can continue on that same level.

Dr. Schmitt and I have submitted written statements and we will strictly highlight what we want to say, and I think Dr. Schmitt should go first, if that's all right with you.

Mr. **Walgren**. That's fine. We are ready to hear you.

STATEMENT OF DR. ROLAND W. SCHMITT, CHAIRMAN, NATIONAL SCIENCE BOARD

Dr. **Schmitt**. Thank you, Mr. Chairman, and other members of the committee, and Mr. Fuqua, and Mr. Lujan. My submitted testimony is before you, and I want to just summarize very, very briefly some of the highlights of that. Really it reinforces what you and Mr. Boehlert have already stated; namely, academic research and education are truly central to our Nation's economy and its defense. We've stressed that on many occasions in the past, and I think that's well recognized.

Our technology strength really depends on the academic base, academic research and education. That technology strength is truly decisive in the world economic competition. It determines which of our industries, which of our defense systems will be surpassed by, stay even with us, or be ahead of foreign competition.

Now, industry does provide many aspects of this technological strength, but there are two things that industry cannot do for itself and cannot produce on its own. The first of those is, of course, trained scientific and engineering talent, and the second is the fundamental, basic scientific and engineering knowledge. It is only the academic science and engineering—our science and engineering base as we have called it—that can provide that.

Now, despite the importance of that, there are signs of wear in this system and the symptoms abound; outdated research equipment, which we find on many campuses; obsolete and inadequate research facilities; declines in the number of Americans receiving Ph.D.'s; and in a concomitant increase in the number of foreign national Ph.D.'s; and in the many problems of science and engineering education today.

So industry, the Federal Government, States, and universities themselves all have to play a role in meeting this need and meeting this agenda of challenges. But the National Science Foundation has a particularly crucial role in this. Although it is less than 3 percent of the Federal R&D budget, it is the one component of that budget that directly addresses and is entirely concerned with the strength of that academic research and engineering base, research and education.

So, from the perspective of competitiveness, in my view, it is the most important. This is the context in which the fiscal year 1987 budget proposal should be judged.

Now I'd like to offer just a few words about the fiscal 1986 authorization bill, which we appreciate very much. The elimination of the restrictions on delegation to the Director of the authority to act on awards has had a very beneficial effect on Board operations. We've taken advantage of this new flexibility to raise the minimum award level that requires Board review to a total of $6 million, and to delegate annually the authority for review of certain large but recurring awards to the Director.

These changes have enabled us to give much more attention to critical strategic issues. The addition of engineering to the NSF Act also reinforces our determination to assure that NSF be attentive to the research and education needs of engineering as well as to science.

Turning back to the budget for a minute, as you have said, Mr. Chairman, as well as Mr. Boehlert, the President is proposing an 8-percent increase for the Foundation. This increase reflects a substantial and a continued commitment to the strength of that base.

In the light of current budget constraints, the increase is indeed substantial. But in the context of the importance of the science and engineering base to the Nation's competitiveness, long-term competitiveness, and of the growing signs of the strain that I mentioned in that base, we believe that this increase is truly critical.

Mr. Chairman, that concludes my very brief summary of the submitted testimony, which you have before you. I thank you for your attention. I'd be happy to answer any questions you may have now, or, if you prefer to wait until after Mr. Bloch has completed his remarks.

[The prepared statement of Dr. Schmitt follows:]

NATIONAL SCIENCE BOARD
WASHINGTON D C 20550

STATEMENT OF

DR. ROLAND W. SCHMITT

CHAIRMAN, NATIONAL SCIENCE BOARD

BEFORE THE SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

ON THE FISCAL YEAR 1987

NATIONAL SCIENCE FOUNDATION AUTHORIZATION

THURSDAY, FEBRUARY 20, 1986

Mr. Chairman and members of the subcommittee:

My primary message this morning is that academic research and education is central to the Nation's economic and defense strength. The international competition of the past decade has been waged, and will continue to be waged, on technological grounds. Our industries that have been surpassed have been surpassed by more advanced technology. Those running neck-and-neck with the competition, such as the semiconductor industry, will only stay that way if they keep pace with foreign technology. And those that are still ahead, such as the computer, aircraft engine, and plastics industry, are ahead because their technology is ahead. It is true that other factors play heavily in the competitive equation. And it is true that we must have a level playing field. But on a level playing field, technology is the distinguishing factor. And when the field is not level, technology is the offsetting factor. If we are to win in international competition, it won't be on the basis of cheaper labor, or cheaper capital, or a favorable exchange rate. It will be on the basis of technology.

From an industrial perspective, by all means the Federal Government must strive to level the playing field. But, just as importantly, it must make the investments in the basic resources needed by industry and defense to win in international competition. Many of the requirements for success lie with actions that only industry can take--streamlining operations, foresight in investment, commitment to R&D, creativity in marketing, and perhaps above all

- and in the decline of science and engineering education across the board.

The agenda, not merely for the Federal Government, but for all of us--for industry, for universities, for the states--is large and growing. But it must be met, unless we are willing to cede our technological leadership to others.

That brings me to the National Science Foundation and its budget for FY 1987. The NSF accounts for a very small portion of the federal R&D budget, less than 5%. But in the context of international competitiveness, it is a critical, high leverage component of the federal budget. It is the one component of that budget directly and entirely concerned not with the pursuit of government missions, but with the strength of academic research and education. It may be the smallest component of the federal R&D budget, but from the perspective of competitiveness, it is the most important. This is the context in which the FY 1987 budget proposal should be judged.

Before Erich Bloch provides you with a more detailed look at the FY 1987 budget proposal, I would like to say a few words about the FY 1986 Authorization Bill.

I would like to thank you, Mr. Chairman, and all the members of the Subcommittee, for your efforts over the past several years to secure a proper authorization for the Foundation. The change made in this year's bill to eliminate the restrictions on the Board's authority to delegate to the Director authority to

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I would like to thank you, Mr. Chairman, and all the members of the Subcommittee, for your efforts over the past several years to secure a proper authorization for the Foundation. The change made in this year's bill to eliminate the restrictions on the Board's authority to delegate to the Director authority to act on awards has had a significant and beneficial effect on Board operations. Since membership on the Board is a part-time occupation, we have been anxious to focus our attention on the points of greatest leverage--receiving programs and plans at an early stage of their formulation and thereby to help guide and shape the priorities of the Foundation.

We have taken advantage of the flexibility offered by the new authorization act to raise the minimum award level that requires Board review to a total of $6 million, which roughly accounts for inflation since the level was last set in 1968. We have also delegated authority for review of certain large but routinely recurring awards to the Director. These changes have enabled us to balance our efforts at project review with considerably more attention to the broader, long-term strategic issues confronting the Foundation.

We greatly appreciate the trust and confidence in the Board and the Foundation that you demonstrated by making this change in the authorization act. We also appreciate the addition of "engineering" to the NSF Act. It acknowledges and reinforces our determination to ensure that NSF be attentive to the research and education needs of engineering as well as science.

Turning back to the budget, the President is proposing an 8% increase for the Foundation and is also proposing real growth in government-wide support for basic research. In the physical sciences and engineering, the increases are even larger. In light of the severe budget constraints that we are operating under, this increase reflects the Administration's continued commitment to the strength of the base. In the context of the budget constraints, the increase is substantial. But in the context of the importance of the science and engineering base to the Nation's competitiveness, and in the context of the growing signs of strain in that base, the increase is also essential.

This year's proposal puts a strong emphasis on four major areas--biotechnology, computational science and engineering, global geosciences, and broadening participation in science and engineering.

Each of these areas significantly affects the health of the science and engineering base. The first three of these strengthen the base at key points of leverage, where major new advances in knowledge are possible, and where the economic effects on important industries are likely to be substantial. The fourth will help build the base by helping to ensure a sufficient supply of high quality scientists and engineers for our future work force.

Each of these emphases crosses disciplinary lines in many ways, and involves many of the Foundation's individual programs. Such cross-disciplinary efforts are important, because it is often at the intersection between old fields that the greatest promise lies.

Each will also foster still more cooperation between universities and industry, and that, too, is part of the solution we are looking for. Both sides benefit when each gains the perspective, experience, and resources of the other.

Mr. Chairman, that concludes my prepared statement. Thank you for your attention. I would be happy to answer any questions you may have now, or, if you prefer, to wait until after Mr. Bloch has completed his remarks.

Mr. WALGREN. Well, let's turn back to Director Bloch.

STATEMENT OF ERICH BLOCH, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. BLOCH. Thank you, Mr. Chairman. The point has been made a couple of times this morning that the NSF budget request is up by about 8.4 percent. And this is a fact, and I think it's in line with previous years submission. And I would like to draw your attention to the chart up there and I think you have copies in front of you.

In 1986 we came to the Congress with a 4.4-percent increase. We left the Congress with a 1.5-percent increase. But I think it signals the administration's emphasis on basic research in science and engineering. It's a basis for economic competitiveness, and I will elaborate on that point a little bit later. It's a basis for product and services that improve all of our lives, and it's a basis for national defense.

Basic research in science and engineering in the United States is synonomous with education, and the two are intertwined because most of our Federal supported basic research, namely about 60 percent of it, is in universities. And the Foundation's budget supports both education and research.

Let me put the NSF budget in perspective with the total Federal R&D budget. On the next chart you see essentially that basic research is 14 percent of the $61 billion Federal R&D budget. NSF's share of that is 16 percent; 16 percent of the 14 percent, or 3 percent of total R&D.

On the next chart you see that basic research is over 50 percent performed in the academic institutions, and NSF's share of that is about 25 percent or $1.4 billion. While NSF is small in total R&D terms, we are significant in the university research and development effort.

Basic research, I want to point out, is a small part of the Federal R&D budget, as I have shown in the last few charts, and the percentage is dropping. This is despite the increases that we have seen. In fact, academic research is even smaller yet and it's also dropping as a percent of the total Federal R&D budget. Even so, in academic basic research you see an increase this year. It just says that other parts of the R&D budgets are growing at a much faster rate.

So what I believe is happening is that we are getting some of the allocations out of kilter; that we are essentially underinvesting in basic research, especially underinvesting in the academic basic research.

Our budget, as you know, has been predominantly in universities, as you can see here, and also in some of the other institutions like NCAR, telescopes, and ships that are also run by universities and serve the universities, and also in precollege education.

We try to address with the budget a number of problems. The first one is economic competitiveness. It's an important subject at this point in our history because we are moving from a creditor nation to one with a growing trade deficit. And the answer is not trade protection. Being first in translating research into new products is the answer, and using new technologies and manufacturing enhances productivity. More than 45 percent of the productivity improvements in the postwar years were due to new scientific and new engineering discoveries and new developments stemming from these areas.

Many of the NSF programs are linked directly to future competitiveness, to future economic competitiveness. I only have to remind you of the ERC's. As you know there are six in existence. We are moving right now to announce five more over the next few weeks. And, as you know, they include examples like telecommunications subject matters, robotics, new materials, systems engineering, and many more subjects.

This budget, 1987, envisions a continuation of the 11 establishments, and adding 4 or 5 more in 1987. As you know, we have a 5-year commitment to these centers. In each year we are spending a significant amount of dollars, and as we increase the number of centers so does the dollar requirement increase on us.

I should tell you that the centers have attracted much support in their existence primarily from industry. In fact, this year—last year and this year together, the centers raised about $13 million of support in addition to the support that the Foundation is providing.

We received 140 proposals the first year, and we received 100 proposals in this year, which shows essentially that there is a need for it. Many more were fundable than it was possible to support. And I want to impress on this committee in particular that not funding should not be interpreted as not making the grade by some of these centers. The cutoff was determined by available budgets and not the quality of the proposals; that we could have funded many more with the same excellence that we funded the first ones.

The ERC's are not the only NSF effort addressing the economic competitiveness. Materials research, chemistry, biotechnology—which is, by the way, one of the special emphasis areas that I will talk about later—computer research and engineering, the small business innovation research activity are all in the economic competitiveness, and many more.

A second area that we are focussing with this particular budget is the development of science and engineering personnel. And this next chart will show you that obviously human sources are—the human resource pool is very critically important. Besides the principal investigators, of which we are supporting about 13,000, the NSF programs are touching 3,700 postdoctorals, 14,000 graduate students, including 1.500 fellows especially in the undergraduate area.

May I see the next chart? You see that over the last few years we have increased the support that flows from our research budgets to these people, that would be our future researchers and our future engineers.

In addition, we are reaching 10,000 teachers through our precollege education program for short periods of time in very special activities, in very special courses.

Another area in the human resources area is broadening the participation. The Foundation has a dual role; first has to stay ahead in research and assure that this country has the best research, and stays ahead of its competition in this particular area, and that the research done is with excellence.

The second one is to ensure the broadest possible participation. There are legitimate considerations of that; geographic distributions, like through our EPSCOR programs; the participation by varied institutions, like undergraduate colleges; the access by all groups of our very heterogeneous society, and we are focussing on minorities and women with some very special targeted and integrated efforts as well.

The Education Directorate, since I am talking about people here, last year I mentioned that we are building the directorate up. We have done that. There was a large carryover from 1985, about $32 million, into 1986. There was a new Assistant Director in place, there were new programs in place, and new people. And I made the point that in all—that we could not support many more activities than what we were supporting at that time.

Second, we wanted to stabilize that particular directorate. The history of the directorate is not the easiest role to explain, and I know you have seen some of the effects of it. This year, I am glad to say, there won't be any carryover into 1987. And there was an increase in this particular budget; it's 2 percent over last year's. I just want to remind you that really the increase is from about $50 million to $89 million, or $82 million (if you take into consideration the carryover) to $89 million.

The Congress added some dollars to it this year, and we're going to spend these dollars obviously, and therefore fulfill our commitment. The staffing is in place, the programs are moving, the funding so far this year is lagging somewhat behind, but we're going to catch up in the next couple of weeks.

The management study which was mandated by Congress has been funded and is in operation. And I think we can look back on the Education Directorate as having done a very good job in the past year.

The third area the budget addresses is the infrastructure. Research depends on people and their ideas, but it also depends increasingly on highly sophisticated, expensive equipment and facilities. And this particular chart essentially shows you what we are spending in this particular area. It's an increasing number essentially.

While we have to level off in 1986 some of the large expenditures, because of the constraint of the budget, this is not an acceptable long-term solution. And we have to look forward for the next few years to finish some of the major programs that we have started.

State-of-the-art instrumentation and equipment has been lagging behind in support over the years. I think over the last few years we have tried to turn the corner on that, but we have to continue to increase the support to instrumentation.

And I informed you also of the important notice that allows grantees to couple facility requirements with their research requests if it's integral and important to the performance of that particular research. So we have opened the door for the scientific community to come in with their requests for facilities.

Obviously we cannot assume a very big burden in that particular area, but we're trying to do essentially what we can do to help that particular area, which I know is of interest to this committee.

One particular infrastructure program that I want to mention is the supercomputer centers. Five have been established in 1985 and 1986. None of them will be established in 1987. We're staying at five. We try to make them as efficient as possible, and the usage is steadily increasing in that particular area. But what we are going to focus on in 1987 is the stability of the centers, the efficiency of the centers, as well as educating the people in the use of supercomputers and doing some networking, part of it that's so important, that interlinks not only supercomputer centers, but interlinks the uses to these very important new tools.

Let me make a couple other comments on general points of the budget. We are supporting many disciplines; from mathematics to behaviorial sciences, from physics and chemistry to engineering disciplines like civil engineering. Some of the work is best suited for individual grants by individual investigators; Some, and an increasing percentage, is concentrated in groups. You can see that on this particular chart here. That's an increasing number. Others in large facilities—as in astronomy, atmospheric, and ocean sciences kinds of facilities. The balance between the three organizations is very important, and we are constantly reassessing this particular balance.

There are some special emphasis areas and I mentioned already two; biotechnology and the broadening aspects on the participation aspect in science. I want to say that even in tight times there is a need to move ahead with new initiatives and into new areas. The opportunities are too great and too important and they don't last forever, and that requires that we prioritize. Not everything can be treated equally, not everything gets the same—and we must change and we must select what is important.

We selected four areas for special emphasis. All of them are multidiscipline areas—three of them are multidiscipline areas; the biotechnology area, which gets a $20 million increase on about a $100 million base; the computer science and engineering area, which is the important multidisciplinary area activity that links and that embraces all of science and all of engineering, is increased by $27 million on a base of $58 million; and the global geosciences area is increased by $17 million on a base of $18 million.

So, in conclusion, I think I—I hope I gave you an overview of the sense of the problem that we see, and the sense of the strategy that we are following. We are encouraged by the President's budget request. It is proper even in this physically constrained year to focus on basic research and education. Basic research is underfunded by any measure, as I said before, and it's an investment for and in the future, not of the past or the present.

The President, in the State of the Union, and the Democratic responses highlighted this area as needing the Nation's focus. And we certainly agree with that. And in light of all this, we ask this committee and Congress' support for the 1987 NSF budget.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Bloch, plus charts used in presentation follow:]

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National
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STATEMENT OF
MR. ERICH BLOCH
DIRECTOR, NATIONAL SCIENCE FOUNDATION
BEFORE THE
SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
FEBRUARY 20, 1986

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE:

IT IS A PLEASURE TO MEET WITH YOU TODAY TO DISCUSS THE FY 1987 BUDGET REQUEST FOR THE NATIONAL SCIENCE FOUNDATION. I WANT TO THANK YOU FOR THE SUPPORT WHICH YOU GAVE TO THE FOUNDATION'S BUDGET LAST YEAR, BUT PARTICULARLY I WOULD LIKE TO COMMEND YOU AND YOUR SENATE COLLEAGUES FOR GETTING AN AUTHORIZATION BILL PASSED AFTER A HIATUS OF SEVERAL YEARS.

I'D LIKE TO TAKE THIS OPPORTUNITY TO SUMMARIZE AND HIGHLIGHT OUR STRATEGY, THE PROBLEMS WITH WHICH WE ARE FACED, AND THE SPECIAL OPPORTUNITIES WHICH OUR BUDGET REQUEST INCLUDES. BEFORE I DO THAT, DR. ROLAND SCHMITT THE CHAIRMAN OF THE NATIONAL SCIENCE BOARD WILL PRESENT THE VIEW OF THE BOARD ON THE BUDGET AND OTHER IMPORTANT ISSUES.

MR. CHAIRMAN, I WANT TO FOCUS ON THE CONTEXT FOR THE 1987 NSF BUDGET: THE IMPORTANCE OF BASIC RESEARCH TO THE NATION, THE STRATEGY UNDERLYING THE 1987 REQUEST, AND SOME HIGHLIGHTS.

BASIC RESEARCH IN THE UNITED STATES

The Federal government will provide about $61 billion for support of R&D activities in FY 1987. Basic research accounts for only $8.6 billion, or 14%, of this total. Federal support of basic research is estimated to increase by 8% in FY 1987. Since a higher percentage increase is projected for support of development activities, the already small share of research dollars that are devoted to basic research is dropping.

Contrary to other countries, in the U.S. about half of all basic research activity takes place in colleges and universities. We have chosen to locate so much of the Federal support for basic research at our academic institutions because in this way we can ensure the continued production of top quality scientists and engineers for academia, industry, and government. As a consequence, higher education and research are inexorably intertwined; supporting one is supporting the other.

The President's Budget Request for NSF shows an increase of 8.4%. This signals the emphasis this Administration places on basic science and engineering as a force for present and future competitiveness, as a prerequisite for the products and services that improve the lives of our citizens, and as a base for building a strong national defense.

THIS INCREASE OCCURS EVEN IN THE FACE OF LARGE FEDERAL DEFICITS AND EFFORTS TO REDUCE FEDERAL SPENDING BECAUSE INVESTMENT IN BASIC SCIENCE AND ENGINEERING IS ESSENTIAL TO IMPROVING OUR COMPETITIVENESS INTERNATIONALLY AND REDUCING OUR TRADE DEFICIT.

NSF HAS A UNIQUE ROLE IN THE FEDERAL SUPPORT OF SCIENCE AND ENGINEERING RESEARCH AND EDUCATION. OUR PROGRAMS PROVIDE SUPPORT FOR PROMISING IDEAS ACROSS ALL FIELDS OF SCIENCE AND ENGINEERING AND COMPLEMENT THE SUPPORT PROVIDED BY THE MORE MISSION-ORIENTED FEDERAL AGENCIES.

NSF ACCOUNTS FOR LESS THAN 3% OF THE FEDERAL SUPPORT FOR TOTAL RESEARCH AND DEVELOPMENT. HOWEVER, IT PROVIDES NEARLY 17% OF FEDERAL BASIC RESEARCH DOLLARS AND ABOUT 25% OF THE FEDERAL SUPPORT FOR BASIC RESEARCH AT COLLEGES AND UNIVERSITIES. THIS SUPPORT ALLOWS RESEARCHERS TO TACKLE PROBLEMS THAT REQUIRE LONGER-TERM INVESTMENTS NOT DIRECTLY DRIVEN BY THE NEED FOR SPECIFIC APPLICATIONS. IT IS FROM SUPPORT SUCH AS THIS THAT GENUINE BREAKTHROUGHS OCCUR, INNOVATION IS STIMULATED AND NOBEL PRIZES ARE EARNED.

PROBLEMS AND BUDGET STRATEGY

THE PROBLEMS THAT WE MUST ADDRESS ARE THE FOLLOWING:

1) OUR SUPPORT OF BASIC RESEARCH AND EDUCATION IN SCIENCE AND ENGINEERING NEEDS STRENGTHENING, TAKING INTO ACCOUNT OUR DEPENDENCE ON THEM, THE INCREASING RATE AT WHICH ADVANCES AND NEW DEVELOPMENTS ARE TAKING PLACE, AND THE PROGRESS (AND INCREASING EMPHASIS) THAT OTHER NATIONS ARE MAKING IN THIS AREA.

2) WE ARE NOT ATTRACTING ENOUGH YOUNG PEOPLE TO SCIENCE AND ENGINEERING TO ASSURE AN ADEQUATE SUPPLY IN THE FUTURE.

3) OUR INVESTMENT IN THE INFRASTRUCTURE OF SCIENCE AND ENGINEERING--EQUIPMENT, INSTRUMENTATION, AND FACILITIES--MUST CONTINUE.

THE FOUNDATION'S BUDGET STRATEGY FOR FY 1987 ADDRESSES THESE ISSUES. THIS STRATEGY

O PROVIDES FOR CONTINUITY BY MAINTAINING BALANCED SUPPORT FOR RESEARCH OF PROVEN QUALITY ACROSS ALL DISCIPLINES.

- ENSURES CHANGE BY INVESTING SIGNIFICANT RESOURCES IN A SELECTED NUMBER OF AREAS THAT OFFER PARTICULAR PROMISE FOR SCIENTIFIC AND ENGINEERING ADVANCES, AND

- STRESSES FISCAL RESPONSIBILITY BY LEVERAGING FEDERAL RESOURCES WHEREVER POSSIBLE AND BY PHASING DOWN OR TERMINATING ACTIVITIES OF LOWER PRIORITY OR LESSER PROMISE.

STIMULATING COMPETITIVENESS AND INNOVATION

ECONOMIC COMPETITIVENESS IS AN IMPORTANT SUBJECT AT THIS TIME IN OUR NATION'S HISTORY. WE HAVE GONE FROM BEING A CREDITOR NATION TO ONE WITH GROWING TRADE DEFICITS. TRADE PROTECTION, HOWEVER, IS NOT THE ANSWER; DEVELOPING AND BEING FIRST IN THE USE OF NEW TECHNOLOGIES IS THE ANSWER. THEREFORE, SUPPORT FOR BASIC RESEARCH AND EDUCATION IN SCIENCE AND ENGINEERING IS ESSENTIAL. EVEN IN THE SHORT TERM, INVESTMENTS IN BASIC RESEARCH WILL HELP TO IMPROVE OUR COMPETITIVENESS. IN THE LONGER RUN, FAILURE TO PROVIDE SUBSTANTIAL SUPPORT FOR BASIC RESEARCH AND EDUCATION IS SURE TO HAVE GRAVE CONSEQUENCES.

THROUGH SUPPORT FOR SUCH PROGRAMS AS THE ENGINEERING RESEARCH CENTERS, INITIATED IN FY 1985, WE ARE PROVIDING OPPORTUNITIES FOR

INDUSTRIAL AND ACADEMIC ENGINEERS AND SCIENTISTS TO WORK TOGETHER IN AREAS OF INQUIRY WHICH REQUIRE A STRONGER FUNDAMENTAL RESEARCH BASE FOR FUTURE ADVANCES. THESE CENTERS ALSO PROVIDE EXPERIENCES FOR UNDERGRADUATE AND GRADUATE STUDENTS WHICH CAN BETTER PREPARE THEM FOR CAREERS IN INDUSTRIAL RESEARCH. SIX CENTERS HAVE BEEN ESTABLISHED. WE WILL VERY SHORTLY ANNOUNCE AWARDS FOR FOUR OR FIVE MORE, AND THE FY 1987 BUDGET REQUEST INCLUDES SUPPORT FOR AN ADDITIONAL FOUR CENTERS.

THERE IS GREAT POTENTIAL FOR LONG-TERM ECONOMIC PAYOFF IN OTHER RESEARCH AREAS, INCLUDING MATERIALS, CHEMISTRY, COMPUTER SCIENCE AND BIOTECHNOLOGY. ALL OF THESE AREAS RECEIVE ENHANCED SUPPORT IN FY 1987, BOTH IN ONGOING BASE PROGRAMS AND THROUGH THE SPECIAL EMPHASIS AREAS OF COMPUTATIONAL SCIENCE AND ENGINEERING, BIOTECHNOLOGY, AND GLOBAL GEOSCIENCES.

OUR EFFORTS IN SUPPORT OF RESEARCH CONDUCTED BY SMALL BUSINESSES AND OF JOINT INDUSTRY-UNIVERSITY RESEARCH VENTURES ARE DIRECTLY AIMED AT ENCOURAGING INNOVATION AND BUILDING STRONGER LINKS BETWEEN BASIC RESEARCH ACTIVITIES OF TODAY AND ECONOMIC ADVANCES IN THE FUTURE.

WE CANNOT TAKE LEADERSHIP IN SCIENCE AND ENGINEERING RESEARCH AND TECHNOLOGY FOR GRANTED. OUR TRADING PARTNERS ABROAD ARE INCREASING VERY SIGNIFICANTLY THEIR COMMITMENTS TO RESEARCH AND THEIR EFFORTS ARE PAYING OFF IN INCREASED WORLD MARKET SHARES. WE

MUST BE WILLING TO INVEST ADEQUATELY TO NARROW THE GAP BETWEEN RESEARCH RESULTS AND THE MARKETPLACE. THE EFFORTS DESCRIBED ABOVE ARE ILLUSTRATIVE OF THE NSF APPROACH TO CONTRIBUTING TO THE MAINTENANCE OF A PREEMINENT POSITION FOR THE U.S. IN ECONOMIC COMPETITION.

DEVELOPING SCIENCE AND ENGINEERING PERSONNEL

THE HUMAN RESOURCE POOL THAT WILL PROVIDE THE SCIENTISTS AND ENGINEERS OF THE FUTURE IS CRITICALLY IMPORTANT. FOR THE YOUNG MEN AND WOMEN ALREADY IN THE CAREER PIPELINE, NSF PROVIDES SUPPORT FOR THE INITIATION OF INDIVIDUAL RESEARCH PROGRAMS AT COLLEGES AND UNIVERSITIES, FOR POSTDOCTORAL OPPORTUNITIES, AND FOR GRADUATE RESEARCH ASSISTANTSHIPS AND FELLOWSHIPS. AT THE UNDERGRADUATE LEVEL, AND PARTICULARLY THE PRECOLLEGE YEARS, WHERE CAREER DECISIONS ARE NOT YET FIRM, THE FOUNDATION DIRECTS SPECIAL EFFORTS TOWARD MAKING SCIENTIFIC AND TECHNICAL CAREERS ATTRACTIVE AND ATTAINABLE. IN ALL OF THESE EFFORTS, INCREASING THE PARTICIPATION OF WOMEN, MINORITIES, AND PHYSICALLY DISABLED PERSONS IN THE SCIENTIFIC AND ENGINEERING ACTIVITIES IS AN IMPORTANT FOUNDATION GOAL.

SUPPORT FOR PRECOLLEGE SCIENCE AND MATHEMATICS ACTIVITIES IS STABILIZED AT THE FY 1986 LEVEL. THE FY 1987 PROGRAM BUILDS ON, AND CONTINUES, ACTIVITIES BEGUN EARLIER. THESE INCLUDE MATERIALS

DEVELOPMENT, INFORMAL EDUCATION, TEACHER PREPARATION AND ENHANCEMENT, AND STUDIES AND ASSESSMENTS. THESE ACTIVITIES ARE ALL CONSISTENT WITH THE FUNCTIONAL OBJECTIVES AS DESCRIBED IN THE REAUTHORIZATION OF THE EDUCATION FOR ECONOMIC SECURITY ACT, P.L. 99-159. ALL OF THE SCIENCE AND MATHEMATICS FIELDS TAUGHT AT THE K-12 LEVELS ARE COVERED. IN THE TEACHER ENHANCEMENT AREA, ABOUT 10,000 TEACHERS PER YEAR ARE PARTICIPATING IN PROJECTS. THE GOAL OF THESE ACTIVITIES IS TO IMPROVE THE QUALITY OF PRECOLLEGE INSTRUCTION IN SCIENCE AND MATHEMATICS, PROVIDE MEANINGFUL OUT-OF-SCHOOL EXPERIENCES FOR YOUNG PEOPLE, AND STIMULATE YOUNG MEN AND WOMEN TO CONSIDER CAREERS IN SCIENCE AND ENGINEERING FIELDS.

THE MANAGEMENT STUDY MANDATED IN THE FY 1985 APPROPRIATION FOR NSF HAS JUST BEEN FUNDED. THE STUDY WILL BE COMPLETED IN 18 MONTHS, WITH SEVERAL INTERIM REPORTS REQUIRED. AS INFORMATION BECOMES AVAILABLE IT WILL BE USED IN UPDATING AND REFORMULATING THE SCIENCE AND ENGINEERING EDUCATION LONG RANGE PLAN.

IMPROVING THE PHYSICAL INFRASTRUCTURE OF SCIENCE AND ENGINEERING

ADVANCES IN SCIENCE AND ENGINEERING ARE INCREASINGLY DEPENDENT ON THE EQUIPMENT AVAILABLE TO RESEARCHERS. INSTRUMENTATION AND FACILITIES MUST BE OF THE HIGHEST QUALITY POSSIBLE IF WE ARE TO MAINTAIN OUR SCIENCE AND TECHNOLOGY BASE AND REALIZE FUTURE ADVANCES.

IN RECENT YEARS, WE HAVE REDUCED OR RESCHEDULED SEVERAL MAJOR CAPITAL INVESTMENTS IN RESEARCH FACILITIES. THIS HAS BEEN A NECESSARY AND APPROPRIATE RESPONSE TO FINANCIAL CONSTRAINTS. HOWEVER, IT DOES NOT CONSTITUTE AN ACCEPTABLE LONG-TERM POLICY FOR RESEARCH SUPPORT. THIS BUDGET INCLUDES SUPPORT FOR ON-GOING CAPITAL IMPROVEMENTS; NO NEW STARTS ARE INCLUDED.

EACH FACILITY IMPROVEMENT HAS BEEN CAREFULLY EXAMINED TO ENSURE THAT THE SUPPORT WE ARE REQUESTING BALANCES THE NEED FOR FISCAL RESTRAINT AND THE SCIENTIFIC NEED FOR THE FACILITY. FOR EXAMPLE, THE CORNELL ELECTRON STORAGE RING UPGRADE WILL CONTINUE (ALTHOUGH ITS COMPLETION WILL BE DELAYED ONE YEAR), WHILE CONSTRUCTION OF THE MICHIGAN STATE UNIVERSITY CYCLOTRON AND THE INDIANA UNIVERSITY COOLER RING WILL BE COMPLETED. SUPPORT FOR THE CONSTRUCTION OF THE VERY LONG BASELINE ARRAY WILL BE MAINTAINED AT ESSENTIALLY THE FY 1986 LEVEL.

MODERN RESEARCH REQUIRES STATE-OF-THE-ART INSTRUMENTATION AND EQUIPMENT. ACCORDINGLY, THE FY 1987 BUDGET REQUEST INCLUDES FUNDS FOR INCREASED INVESTMENT IN DISCIPLINE-SPECIFIC RESEARCH INSTRUMENTATION PROGRAMS AND FOR AN EXPANSION OF THE COLLEGE SCIENCE INSTRUMENTATION PROGRAM. TOTAL SUPPORT FOR INSTRUMENTATION AND EQUIPMENT INCREASES FROM $223 MILLION IN FY 1986 TO $260 MILLION IN FY 1987. INCREASES FOR INSTRUMENTATION

OCCUR THROUGHOUT THE DISCIPLINES SUPPORTED BY THE FOUNDATION, WITH SPECIAL ATTENTION FOCUSED ON THE BIOLOGICAL SCIENCES THIS YEAR.

LEVERAGING FEDERAL DOLLARS

NSF CONTINUES IN FY 1987, AS IN PREVIOUS YEARS, TO LEVERAGE FEDERAL DOLLARS BY ENCOURAGING AND REQUIRING THE PARTICIPATION OF PRIVATE SECTOR ORGANIZATIONS, ACADEMIC INSTITUTIONS, AND STATE AND LOCAL GOVERNMENTS AS PARTNERS IN FUNDING RESEARCH AND EDUCATION. SOME PROGRAMS REQUIRE CONTRIBUTIONS FROM THESE AND OTHER SOURCES.

EXAMPLES OF THE SUCCESSES WE HAVE ACHIEVED IN ATTRACTING OUTSIDE FUNDING TO COMPLEMENT AND EXTEND THE SUPPORT BY NSF:

- THE SIX ENGINEERING RESEARCH CENTERS ESTABLISHED LAST YEAR HAVE GENERATED APPROXIMATELY $13 MILLION IN INDUSTRIAL SUPPORT;
- THE THREE NATIONAL ADVANCED SCIENTIFIC COMPUTING CENTERS WHICH WERE ALSO INITIATED LAST YEAR HAVE RAISED A 40 CENT MATCH FOR EVERY DOLLAR THE FEDERAL GOVERNMENT SPENDS;
- THE $5.5 MILLION PROVIDED FOR THE FY 1985 COLLEGE SCIENCE INSTRUMENTATION PROGRAM AWARDS WILL BE

MATCHED BY AT LEAST AN EQUAL AMOUNT; AND

- THE FY 1984 CLASS OF PRESIDENTIAL YOUNG INVESTIGATORS HAS SUCCEEDED IN OBTAINING NEARLY $11 MILLION IN MATCHING FUNDS.

- SO FAR DURING FY 1986, $1.9 MILLION NSF INVESTMENT IN PRECOLLEGE INSTRUCTIONAL DEVELOPMENT HAS BEEN MATCHED BY NEARLY $9 MILLION FROM OTHER SOURCES.

THE NSF BUDGET REQUEST FOR FY 1987

THE STRATEGY WE HAVE ADOPTED IS EMBODIED IN THE FOUNDATION'S FY 1987 BUDGET REQUEST, WHICH TOTALS $1,685.7 MILLION OR 8.4% ABOVE THE FY 1986 CURRENT PLAN OF $1,555.6 MILLION. IT INCLUDES:

- $1,479 MILLION FOR RESEARCH AND RELATED ACTIVITIES, AN INCREASE OF 9.4%.

- $117 MILLION FOR THE U.S. ANTARCTIC PROGRAM (USAP), UP 1.6%. (A BUDGET BASE TRANSFER OF $14.4 MILLION WAS MADE TO THE U.S. COAST GUARD TO COVER BASIC ICEBREAKER SERVICES. THOSE FUNDS INCLUDE PART OF A $3.0 MILLION INCREASE IN COAST GUARD CHARGES, THUS THE EFFFECTIVE INCREASE FOR USAP IN FY 1987 IS 11.3%.)

- $89 MILLION, OR A 2.3% INCREASE, FOR SCIENCE AND ENGINEERING EDUCATION. (THE CARRYOVER OF $31.5 MILLION FROM FY 1985 INTO FY 1986 HAS BEEN MADE PART OF THE BASE FOR SCIENCE AND ENGINEERING EDUCATION.)

- $0.7 MILLION IN SPECIAL FOREIGN CURRENCY FUNDS.

THIS BUDGET REQUEST, IF APPROVED BY CONGRESS:

- WILL MAINTAIN BALANCED SUPPORT FOR RESEARCH OF PROVEN QUALITY ACROSS ALL DISCIPLINES.

- WILL ALLOW SIGNIFICANT INCREASES FOR A SMALL NUMBER OF MULTIDISCIPLINARY SPECIAL EMPHASIS AREAS WHERE ADDITIONAL FUNDING CAN HAVE A MULTIPLIER EFFECT BY ESTABLISHING NEW INSTITUTIONAL ARRANGEMENTS AND CAPABILITIES FOR ENCOURAGING THE COLLABORATION THAT ACCELERATE SCIENTIFIC PRODUCTIVITY.

- WILL PROVIDE SUPPORT FOR FACILITIES WHICH ARE AN INTEGRAL PART OF RESEARCH ACTIVITIES IN FIELDS SUCH AS PHYSICS, MATERIALS, ADVANCED SCIENTIFIC COMPUTING, ASTRONOMY, AND THE GEOSCIENCES.

- WILL STABILIZE FUNDING FOR THE SCIENCE AND ENGINEERING EDUCATION ACTIVITY, MAINTAINING THE FY 1986 LEVEL

FOR GRADUATE AND PRECOLLEGE PROGRAMS AND AN INCREASE FOR THE COLLEGE SCIENCE INSTRUMENTATION PROGRAM.

SPECIAL EMPHASES FOR FY 1987

FOUR AREAS HAVE BEEN IDENTIFIED FOR SPECIAL EMPHASIS IN FY 1987: THREE SCIENTIFIC RESEARCH AREAS AND ONE INFRASTRUCTURE AREA. THE THREE SCIENTIFIC AREAS ARE BIOTECHNOLOGY, COMPUTATIONAL SCIENCE AND ENGINEERING AND GLOBAL GEOSCIENCES. EACH IS MULTIDISCIPLINARY IN NATURE, AND THIS DEMANDS COLLABORATIVE EFFORTS AND SOPHISTICATED EQUIPMENT. THEY ARE AREAS WHERE ADDITIONAL FUNDING CAN HAVE A LARGE MULTIPLIER EFFECT BY ESTABLISHING NEW INSTITUTIONAL ARRANGEMENTS FOR ENCOURAGING THE COLLABORATION THAT WILL ACCELERATE AND INTENSIFY SCIENTIFIC PRODUCTIVITY. THE FOURTH EMPHASIS ADDRESSES THE NEED TO BUILD A STRONG, DIVERSE BASE, BOTH OF PEOPLE AND INSTITUTIONS, FOR THE PERFORMANCE OF RESEARCH IN THE FUTURE.

BIOTECHNOLOGY

THE BIOTECHNOLOGY INDUSTRY IN THE U.S. IS A SUCCESSFUL AND GROWING ENTERPRISE. THE U.S. IS CURRENTLY THE WORLD LEADER IN MANY ASPECTS OF BIOTECHNOLOGY. THAT LEADERSHIP CANNOT BE MAINTAINED WITHOUT CONTINUED EFFORT.

THE SUCCESS OF COMMERCIAL BIOTECHNOLOGY RELIES HEAVILY ON THE FUNDAMENTAL RESEARCH BASE AND IS INCREASINGLY MULTIDISCIPLINARY IN NATURE. FUTURE ADVANCES WILL REQUIRE:

O ENHANCED DEVELOPMENT OF THE KNOWLEDGE BASE, ESPECIALLY IN AREAS WITH GAPS THAT LIMIT PROGRESS, AND

O SCIENTISTS AND ENGINEERS WITH SOLID DISCIPLINARY TRAINING AND SKILLS, WORKING IN RESEARCH ENVIRONMENTS THAT ENCOURAGE MULTIDISCIPLINARY EFFORTS.

THE FOUNDATION HAS INCREASED SUPPORT FOR FUNDAMENTAL BIOTECHNOLOGY-RELATED RESEARCH OVER THE PAST SEVERAL YEARS. OUR FIRST EFFORTS WERE MAINLY AIMED AT INCREASING SUPPORT FOR THE PLANT SCIENCES, INCLUDING THE ESTABLISHMENT OF A PLANT SCIENCES POSTDOCTORAL FELLOWSHIP PROGRAM. IN FY 1985, ATTENTION WAS DIRECTED TO THE INITIATION OF COLLABORATIVE EFFORTS BETWEEN CHEMISTS AND BIOLOGISTS TO GAIN A DEEPER UNDERSTANDING OF LIFE PROCESSES. IN THE ENGINEERING RESEARCH CENTER PROGRAM AN AWARD WAS MADE TO THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY TO ESTABLISH A CENTER FOR BIOTECHNOLOGY PROCESS ENGINEERING.

FOR FY 1987, AN INCREASE OF $20 MILLION IS REQUESTED OVER THE FY 1986 LEVEL OF $86.5 MILLION. THE INCREMENTAL FUNDS WILL BE USED FOR MULTIDISCIPLINARY RESEARCH CENTERS, MULTI-USER EQUIPMENT, AND CROSS-DISCIPLINARY RESEARCH AND TRAINING PROGRAMS.

COMPUTATIONAL SCIENCE AND ENGINEERING

ADVANCED RESEARCH IN MANY AREAS OF SCIENCE AND ENGINERING INCREASINGLY RELIES ON COMPUTATIONAL METHODS TO CALCULATE, SIMULATE, AND MODEL COMPLEX RELATIONSHIPS, NEW CONCEPTS AND IDEAS. THIS APPROACH IS COMPLEMENTARY TO THE TRADITIONAL EXPERIMENTAL AND THEORETICAL APPROACHES AND PROVIDES AN IMPORTANT NEW TOOL THAT ENHANCES AND ACCELERATES SCIENTIFIC PROGRESS.

UNTIL RECENTLY, THE U.S. ACADEMIC RESEARCH COMMUNITY HAD LIMITED OPPORTUNITY TO EMPLOY ADVANCED COMPUTATIONAL METHODS BECAUSE OF THEIR LACK OF ACCESS TO THE MOST ADVANCED COMPUTERS. NSF BEGAN TO ADDRESS THIS NEED IN FY 1985 WITH THE ESTABLISHMENT OF NATIONAL SUPERCOMPUTING CENTERS AND THE PROVISION OF INCREASED ACCESS TO ADVANCED COMPUTERS TO SCIENTISTS AND ENGINEERS FROM MANY DISCIPLINES. THE EFFORT HAS BEEN LARGELY SINGLE-INVESTIGATOR CENTERED.

THE FY 1987 EMPHASIS ENCOURAGES COLLABORATIVE, MULTIDISCIPLINARY APPROACHES TO COMPLEX PROBLEMS,THUS CAPITALIZING ON THE DIFFERENT PERSPECTIVES OF MATHEMATICIANS, COMPUTER SCIENTISTS AND SCIENTISTS AND ENGINEERS FROM OTHER DISCIPLINES.

IN FY 1986, APPROXIMATELY $57 MILLION WILL BE ALLOCATED TO COMPUTATIONAL SCIENCE AND ENGINEERING ACTIVITIES. IN FY 1987, AN

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ADDITIONAL $27 MILLION IS REQUESTED TO ESTABLISH NEW MULTIDISCIPLINARY TEAMS, ENHANCE EXISTING CENTERS AND GROUPS, AND PROVIDE EQUIPMENT AND TRAINING OPPORTUNITIES.

GLOBAL GEOSCIENCES

THE FY 1987 BUDGET REQUEST SEEKS AN INCREASE OF $18 MILLION, OVER AN ESTIMATED FY 1986 BASE OF $17 MILLION, FOR INCREASED EMPHASIS ON GLOBAL GEOSCIENCES THROUGH A SERIES OF INTERRELATED RESEARCH EFFORTS TREATING THE EARTH AS AN INTEGRATED SYSTEM OF PHYSICAL, CHEMICAL, AND BIOLOGICAL PROCESSES. DISCIPLINES FROM THE ATMOSPHERIC, ASTRONOMIC, EARTH AND OCEAN SCIENCES ACTIVITY AND THE BIOTIC SYSTEMS AND RESOURCES SUBACTIVITY OF THE BIOLOGICAL, BEHAVIORAL, AND SOCIAL SCIENCES ACTIVITY WILL PARTICIPATE IN THE EMPHASIS. THERE WILL ALSO BE SIGNIFICANT PARTICIPATION IN THESE ACTIVITIES BY OTHER AGENCIES, INCLUDING NASA, NOAA, AND THE USGS.

STUDIES OF GLOBAL OCEAN AND ATMOSPHERIC CIRCULATION, CHEMISTRY OF THE TROPOSPHERE, ECOSYSTEM DYNAMICS, BIOLOGICAL DIVERSITY AND PRODUCTIVITY, AND SOLID EARTH PROPERTIES WILL BE SUPPORTED. THE RESULTS WILL PROVIDE COHESIVE APPROACHES TO STUDIES OF THESE AREAS, CREATE NEW DATA SETS, AND DIRECTLY INVIGORATE THE CONSTITUENT BASIC SCIENCE DISCIPLINES.

THE ACTIVITIES WHICH WILL BE FUNDED THROUGH THIS EMPHASIS ARE PART OF MAJOR INTERNATIONAL EFFORTS TO UNDERSTAND NATURAL PHENOMENA

WHICH CROSS REGIONAL AND NATIONAL BOUNDARIES. INCREASED UNDERSTANDING OF THESE PROCESSES CAN LEAD TO BETTER PREDICTIVE MODELS FOR NATURAL EVENTS SUCH AS THE EL NINO OCEANIC/ATMOSPHERIC PHENOMENON, EARTHQUAKES AND VOLCANIC ERUPTIONS, AND THE CONSEQUENCES OF HUMAN ACTIVITY , SUCH AS ACID RAIN AND DEFORESTATION.

BROADENING PARTICIPATION IN SCIENCE AND ENGINEERING

THE FOUNDATION HAS A DUAL ROLE IN THE SUPPORT OF THE PEOPLE AND INSTITUTIONS THAT WILL BE THE PERFORMERS OF SCIENCE AND ENGINEERING RESEARCH IN THE FUTURE:

- TO ASSURE THE EXCELLENCE OF OUR RESEARCH, TIMELY DISCOVERIES, AND THE QUALITY OF EDUCATION TO KEEP THE U.S. COMPETITIVE IN TOMORROW'S WORLD; AND

- TO ENSURE THAT THE BROADEST POSSIBLE RANGE OF TALENT, BOTH OF PEOPLE AND INSTITUTIONS, IS ABLE TO PARTICIPATE IN SCIENTIFIC AND ENGINEERING RESEARCH.

IN CARRYING OUT THESE RESPONSIBILITIES, ISSUES OF GEOGRAPHIC, INSTITUTIONAL, AND PERSONNEL DISTRIBUTION ARE RECOGNIZED AS LEGITIMATE CONSIDERATIONS IN THE DEVELOPMENT AND MAINTENANCE OF OUR SCIENCE AND ENGINEERING BASE.

THE FOUNDATION HAS EMPLOYED TARGETED PROGRAMS AS WELL AS EFFORTS INTEGRATED INTO ALL OF THE AGENCY'S PROGRAMS IN ITS EFFORTS TO BROADEN PARTICIPATION IN SCIENCE AND ENGINEERING. FOR FY 1987 THIS BASIC STRATEGY CONTINUES AND IS ENHANCED.

PROGRAMS AIMED AT INCREASING THE PARTICIPATION OF WOMEN AND MINORITIES ARE OF BOTH TYPES: TARGETED AND MAINSTREAMED. FOR EXAMPLE, THE VISITING PROFESSORSHIPS FOR WOMEN PROGRAM IS LOCATED IN THE STIA ACTIVITY, AS IS THE RESEARCH IMPROVEMENT IN MINORITY INSTITUTIONS PROGRAM. BOTH OF THESE PROGRAMS ARE CENTRALLY MANAGED AND BUDGETED. BOTH ARE MAINTAINED AT THE FY 1986 LEVEL. ON THE OTHER HAND, RESEARCH INITIATION PROGRAMS FOR MINORITIES AND WOMEN HAVE BEEN MAINSTREAMED: DISCIPLINARY RESEARCH PROGRAMS ARE RESPONSIBLE FOR BUDGETING AND MANAGING THESE EFFORTS WHILE STIA PROVIDES FOUNDATION-WIDE COORDINATION AND MONITORING. THE TARGETS FOR BOTH OF THESE RESEARCH INITIATION EFFORTS ARE INCREASED FOR FY 1987.

IN FY 1987, A NEW PROGRAM, MINORITY RESEARCH CENTERS OF EXCELLENCE, IS INCLUDED IN THE BUDGET REQUEST FOR THE SCIENTIFIC, TECHNOLOGICAL AND INTERNATIONAL AFFAIRS ACTIVITY. THROUGH THIS PROGRAM, A SMALL NUMBER OF MINORITY INSTITUTIONS THAT HAVE STRONG SCIENCE OR ENGINEERING PROGRAMS WILL BE ASSISTED IN BECOMING CENTERS OF EXCELLENCE. THESE CENTERS WILL CONDUCT RESEARCH, PROVIDE GRADUATE TRAINING, WORK WITH ASSOCIATED UNDERGRADUATE

INSTITUTIONS, ESTABLISH STRONG TIES WITH NEARBY PRECOLLEGE TEACHERS AND SCHOOLS, AND SERVE AS COMMUNITY RESOURCES FOR STIMULATING MINORITY YOUNG PEOPLE TO CONSIDER CAREERS IN SCIENCE AND ENGINEERING.

FOR THE LAST SEVERAL YEARS, NSF HAS INCREASED ITS SUPPORT OF UNDERGRADUATE RESEARCH AND EDUCATION, LARGELY THROUGH ITS FOCUS ON RESEARCH IN PREDOMINANTLY UNDERGRADUATE INSTITUTIONS. IN FY 1987 SIGNIFICANT ENHANCEMENT AND EXTENSION OF THIS EFFORT IS PROPOSED. UNDERGRADUATE FACULTY AND STUDENT RESEARCH OPPORTUNITIES WILL BE INCREASED, REGARDLESS OF THE PARENT INSTITUTION SIZE AND ORIENTATION. SUPPORT FOR UNDERGRADUATE INSTRUCTIONAL INSTRUMENTATION WILL BE INCREASED THROUGH THE COLLEGE SCIENCE INSTRUMENTATION PROGRAM. THE FOCUS ON SUPPORT FOR RESEARCH AT PREDOMINANTLY UNDERGRADUATE INSTITUTIONS WILL CONTINUE IN ALL THE RESEARCH PROGRAMS OF THE FOUNDATION.

FINALLY, THE EXPERIMENTAL PROGRAM TO STIMULATE COMPETITIVE RESEARCH (EPSCoR) WILL BE CONTINUED AND ENHANCED. THE PROGRAM PROVIDES MODEST FUNDS FOR PLANNING AND IMPLEMENTATION TO BUILD SCIENCE AND ENGINEERING CAPACITY IN STATES THAT HAVE NOT RECEIVED LARGE NUMBERS OF NSF AWARDS. UP TO EIGHT AWARDS WILL BE MADE IN FY 1987.

OTHER NSF EFFORTS TO BUILD THE SCIENTIFIC AND ENGINEERING PERSONNEL POOL FOR THE FUTURE WILL CONTINUE. THESE INCLUDE THE

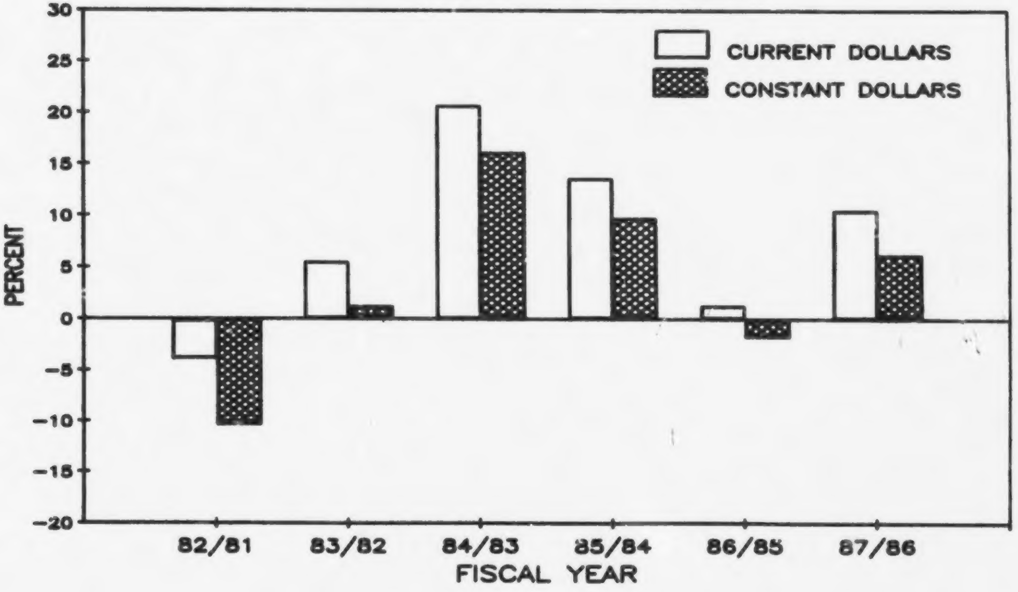
Graduate Fellowships Program, graduate research assistantships, postdoctoral research asssociates, and Presidential Young Investigator awards.

Through these complementary approaches, NSF will contribute to building a scientific and engineering workforce that is characterized both by excellence and diversity.

CONCLUSION

Mr. Chairman, I hope that this overview provides a sense of the problems we are facing and the strategy we have chosen to address them. We are encouraged by the budget request level that the President has sent forward. We, of course, believe that science and engineering are keys to the future well-being of our country. I hope that the final action taken by the Congress on the National Science Foundation's FY 1987 Budget Request will help us ultimately to provide those keys for the Nation, and we ask for this Committee's support toward that end.

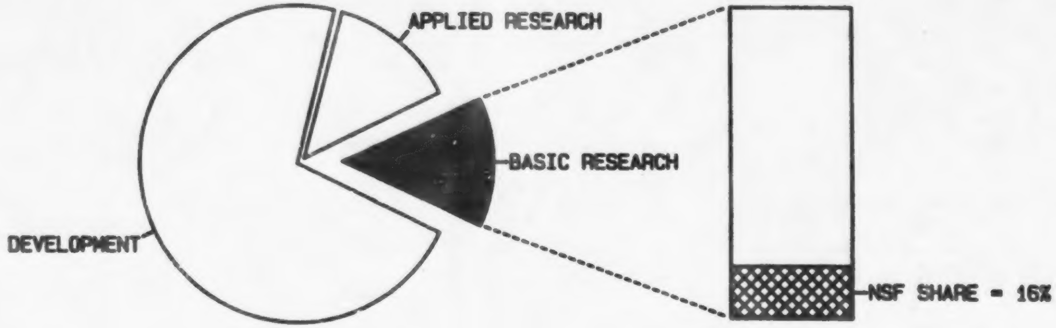
NATIONAL SCIENCE FOUNDATION
APPROPRIATION TRENDS
1982 — 1987
INCREASE OVER PRIOR YEAR



37

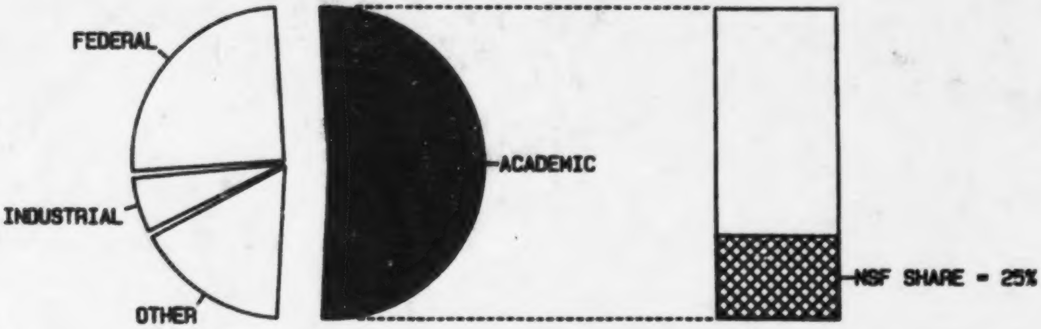
FEDERAL SUPPORT FOR R&D, FY 1987

- BY CHARACTER OF WORK -



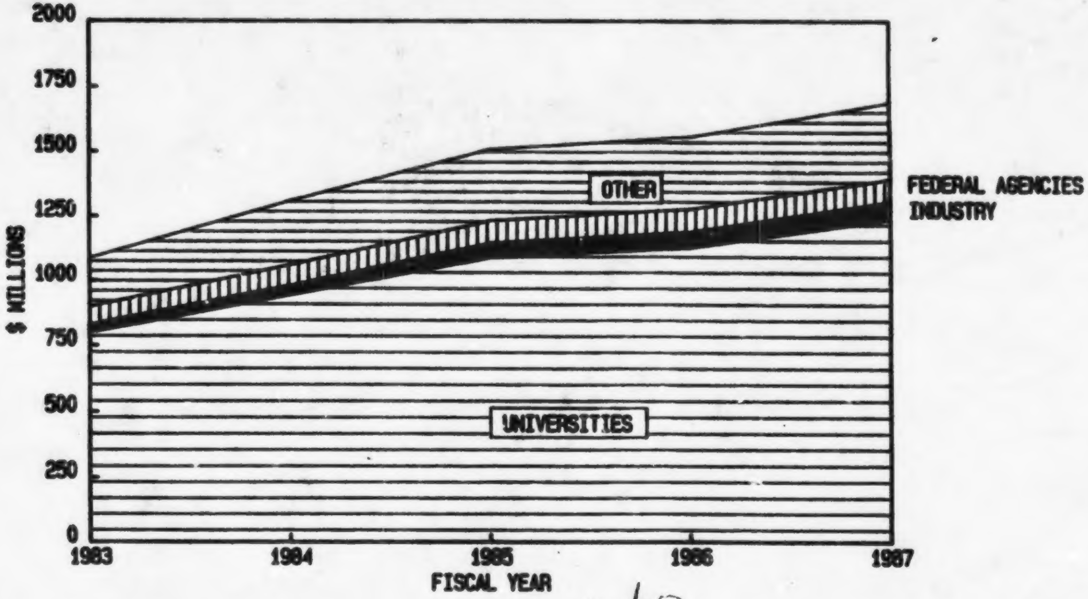
FEDERAL SUPPORT FOR BASIC RESEARCH, FY 1987

- BY MAJOR PERFORMER -



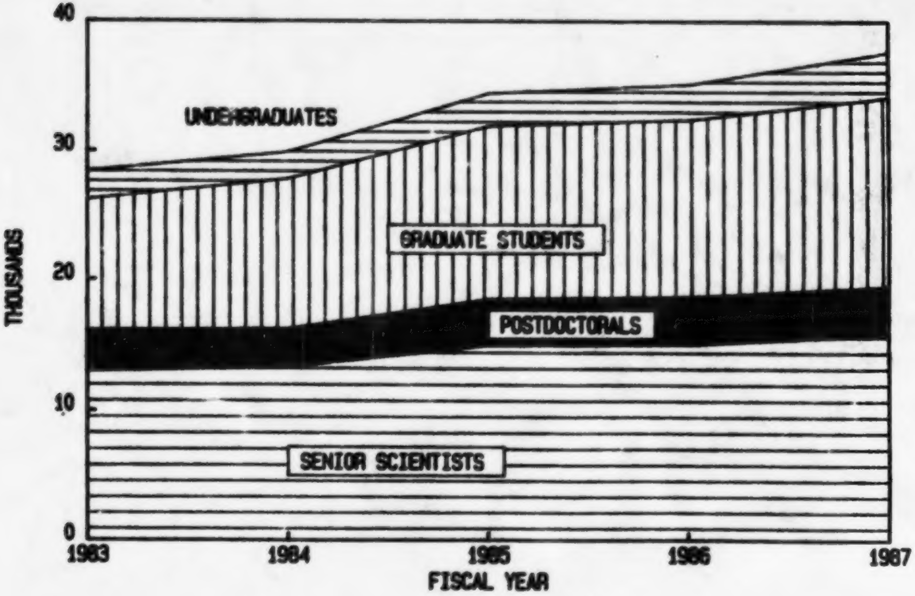
NATIONAL SCIENCE FOUNDATION
DOLLAR DISTRIBUTION BY PERFORMER

1983 - 1987



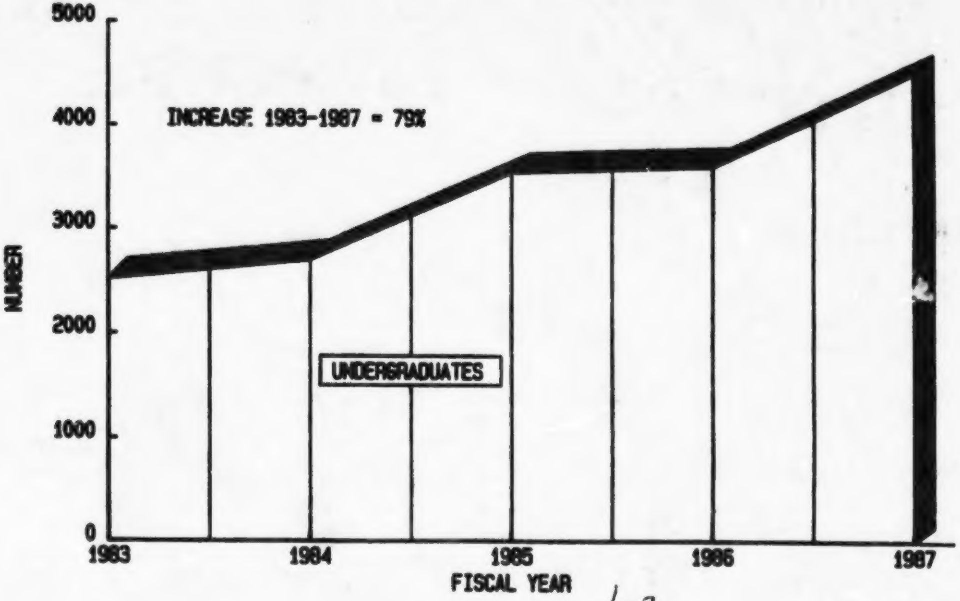
NATIONAL SCIENCE FOUNDATION RESEARCH GRANT PERSONNEL

1983 - 1987



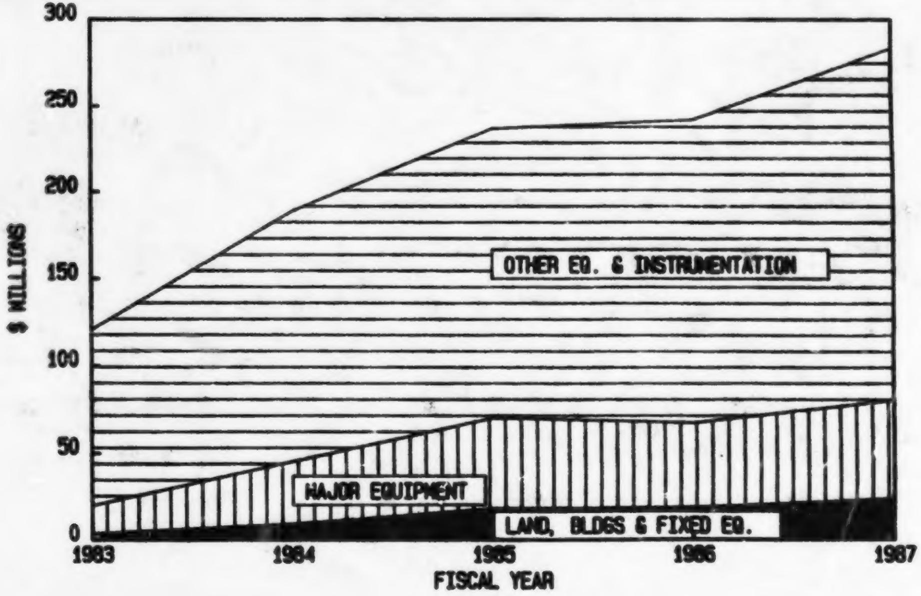
NATIONAL SCIENCE FOUNDATION
UNDERGRADUATE SUPPORT

FY 1983 - FY 1987

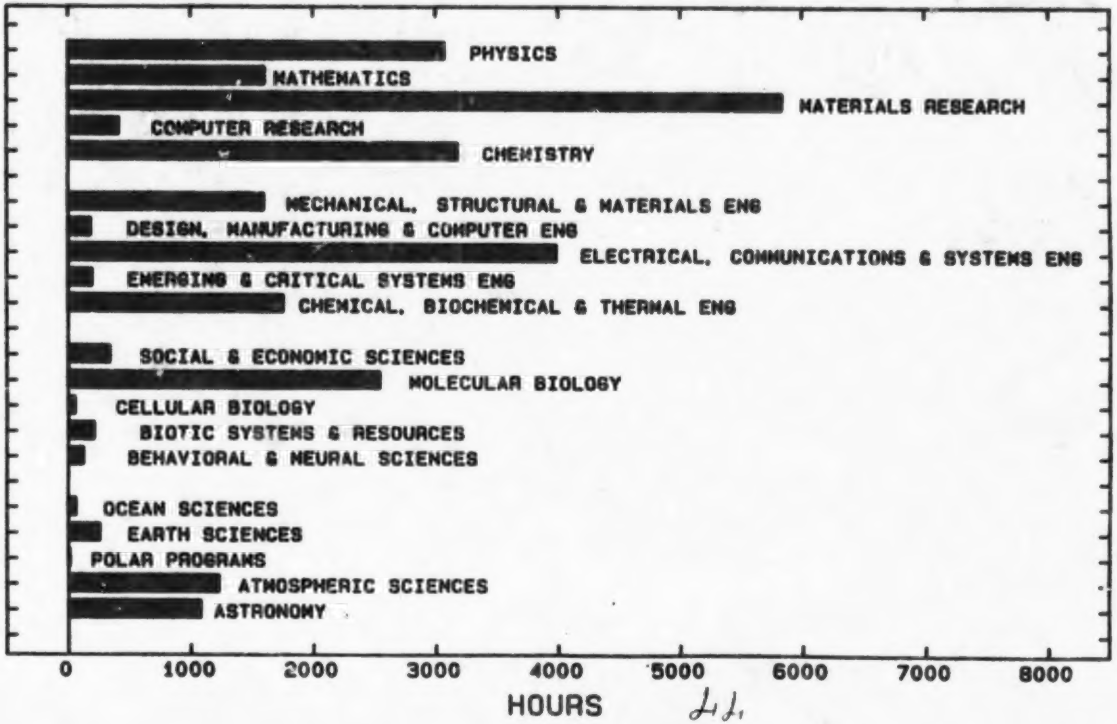


NATIONAL SCIENCE FOUNDATION EQUIPMENT CATEGORIES

1983 - 1987

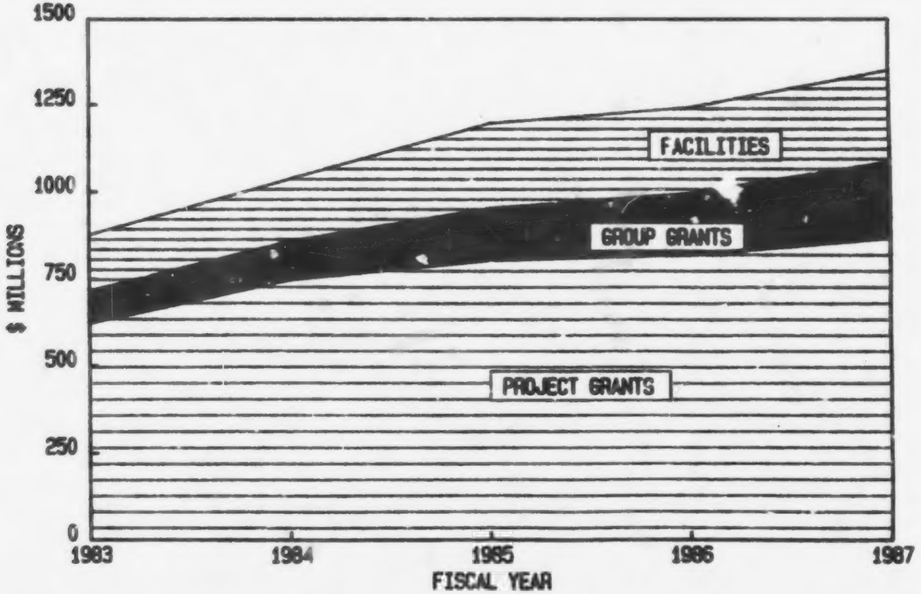


SUPERCOMPUTER ALLOCATION
BY PROGRAM
AUGUST 1984 - NOVEMBER 1985



NATIONAL SCIENCE FOUNDATION
PROJECT BALANCE

FY 1983 - FY 1987



* INCLUDES MPS, AAEO, BBS, ENG, & ASC ONLY

Mr. **Walgren**. Thank you very much, Mr. Bloch. That's a good introduction to the range of concerns that you're trying to address and we certainly appreciate that.

Let me ask or give you an opportunity to expand perhaps a little bit beyond just the focus of NSF this concept of underinvesting in basic research, because I think we are all, on this side of the ledger, concerned about the range of science programs. And we see in our responsibilities proposals in other areas as well as just the NSF.

And this problem of underinvesting in the area of basic research is really something that we ought to be focussed on. I wonder whether there's any more creative roles other than a commentator that someone like yourself might play, or the National Science Board, or something like that to try to make that point more broadly in the Government.

Mr. **Bloch**. Well, let me comment on that and then probably Dr. Schmitt would like to comment on that one also. I meant it when I said we are underinvesting in basic research, and I showed you the small numbers that go into basic research.

And also the storm signal is really on the horizon when you see that basic research as a part of the total R&D budget is dropping, and when you see academic basic research is dropping as a percent of the total Federal R&D budget. That should tell us something.

Second, if you look at the areas, at the problem areas—and now I focus primarily on academic research—the facilities problems, the instrumentation problem that I highlighted before. The fact that we are not attracting enough people to science and engineering, and that we probably will attract fewer in the next 10 years strictly from a demographic viewpoint—because a 22-year cohort is dropping—and the attraction rate to science and engineering has stayed fairly flat and fairly constant over a 10-year period or even a longer period, I think should give us some cause for concern.

I'm not saying that one needs to increase the production of engineers and scientists and Ph.D.'s, but just to stay level with what we are producing I think should give us some concern. And you know quite well that Japan is producing twice the number of electrical engineers than we do.

And, by the way, they are concerned that they will not produce enough engineers in the future as we have seen over the last few weeks in many of the papers. So all of that I think should give us some concern.

Now, what can be done about it? Well, the first thing, I think over the last few years you have seen it happening. There has been a redirection of development dollars, Federal development dollars into basic research, and that's why you saw the increases especially in the National Science Foundation. That has to continue. It's probably not enough. We need to step that one up if that is possible.

Second, if you see what the other agencies are doing in basic research, some of the agency's basic research as a percent of their R&D dollars is dropping. And obviously this should give us concern. By the way, I'm not saying that all basic research should be funded by the National Science Foundation, not at all. It doesn't matter really who funds it and who has the budget and who has the responsibility, as long as there are money and people and ideas flowing from that particular effort. That's an important aspect.

Mr. WALGREN. Dr. Schmitt, would you like to comment on that?

Dr. SCHMITT. Yes; I would like to first of all endorse and emphasize what Mr. Bloch has said. I do not believe that the NSF budget can, by itself, correct the very deep seated and serious problems that we have with the academic research and education base today.

So, to my mind, one has to also get many of the mission agencies to really look at the implications of their needs for their missions in academic research and to pay attention to the problem also.

The problem is being underscored, I think, in the next few years with the need to replace a lot of the faculty in universities. And that's going to need to take place at a very time when our production of Ph.D.'s in many crucial areas—like engineering—is going down.

So in addition to all the other items that indicate the really serious needs in the academic research community, like the outdated research equipment, inadequate facilities, and so on, we have real manpower issues in the academic community also.

So my own feeling, from my perspective as Chairman of the National Science Board and in industry, simply serves to reemphasize what Mr. Bloch has said about the really desperate needs out there today.

Mr. WALGREN. Let me ask whether you see the mechanism to make that point in a coordinated way. Here we are in the National Science Foundation, and we're sort of pointing at a need, and there are all these other players. And is there the danger that because we must rely on so many different independent segments of our society to contribute to this problem, that we're not able to get other participants running with us on this theme?

Dr. SCHMITT. Well, I believe that one simply has to get a better understanding of the need. I mean, when you're in a mission oriented agency, as I am personally in a sense in industry, one always looks at your immediate and current needs as the most pressing. And it really requires a continuing emphasis of the fundamental need that you have for input from academic research to appreciate that.

Industry, I might say, has in fact responded to that over the past few years because there's an increasing amount of industrial money going into academic research. But it's still, at best, going to be a very small fraction. I think you've got to get many of the mission oriented agencies of the Federal Government to understand similarly that they are truly dependent upon this base.

Mr. BLOCH. Can I comment on that also? Let me comment first on the relationship with the other agencies. We're doing many things together. And there are many places where we coordinate our effort. Certainly the supercomputer center area is one. Last year in the engineering research center area, NIH cofunded one of the centers, the biotechnology center with us. There are many other places, with DARPA, where we have common programs. But I must say it's on an ad hoc basis, and it's usually in an area like supercomputers or like engineering research centers that are special initiatives or special activities. Not the run of the mill kind of basic research.

We are trying to leverage our funds—research in many of the programs like the engineering research centers, like the supercomputer centers, like the Presidential Young Investigator programs. We are trying to pull in industrial dollars to help essentially enhance the support that goes to universities. And I think we have been fairly successful. We have a long ways to go, even in that area.

Mr. **Walgren**. The Chair would recognize Mr. Boehlert.

Mr. **Boehlert**. Thank you, Mr. Chairman. Mr. Bloch, let me give a preamble to the question. I don't want you to get nervous because this is not an advocacy question. It's one to establish the record.

What would be the first projects that you would have to cut if you got your budget reduced by Congress or through Gramm-Rudman? And would you have to eliminate any programs altogether?

Mr. **Bloch**. Well, you have to tell me first by how much I have to cut.

Mr. **Boehlert**. Well, if it was up to me it wouldn't be any. So, don't worry, don't get nervous.

Mr. **Bloch**. All right. Well, let me answer the question, and I'll take the 1986 example, where we had in the middle of the year, in the middle of the fiscal year; namely as of March 1, where we had to cut 4.3 percent of our budget.

We did not eliminate any programs per se, but we hit certain areas harder than others. We are trying to protect certain areas so that the effect essentially will not be uniform across all of the Foundation's areas, divisions, or directorates.

So with the 4.3-percent cut you can do that. If you had to go to a 10-percent cut or a 15-percent cut, or like some people are saying a 20-percent cut, then I think you have to think of closing down facilities in a very serious kind of a way. Now, that won't be very easy. It also will not be very easy to identify those that you should shut down, but I think you have to go through a priority analysis of it.

I think we have to look at certain disciplines and see if you don't want to shed certain disciplines, not to support them for——

Mr. **Boehlert**. If I may right here. Just, for example, supposing it was an 8.4-percent cut—because unfortunately the mentality of some people around here is to freeze everything; the good, the bad, the indifferent—but suppose it was in that magnitude. Would you lose any new initiatives, for example?

Mr. **Bloch**. We probably would have to sacrifice a particular initiative, yes. I can't tell you at this point which one. But it doesn't make much sense that you cut every one down to a point where they are subcritical in mass. That would be my concern. Maybe we would defer some of the engineering research centers next year. We might have to go to that.

Certainly we would like to see if we can close some facilities down altogether, maybe some of the materials research labs, or what have you. It would be a difficult kind of a decision. But when you get in with an 8.4 percent, you have to close down certain things very clearly.

Mr. **Boehlert**. Are you still using my example I gave you last year? Cigarette excise tax.

Mr. **Bloch**. No. I think we lost that example.

Mr. **Boehlert**. Oh, it's a great example.

Mr. **Bloch**. It's a great example, I know, but it didn't help very much.

Mr. **Boehlert**. Well, we're still working on that problem. I'd like to get the commitment from my colleagues up here because, you know, the excise tax on cigarettes comes up March 15. It's due to be cut in half from 16 cents to 8 cents a pack. Just by retaining it at the 16-cent level and using this—and, Dr. Schmitt, you can, too—we can fund the entire budget of the National Science Foundation.

Dr. Schmitt, the Science Board has a report due in March on undergraduate education. Can you give us any hints of what you might be saying in that report, some of the recommendations?

Dr. **Schmitt**. Well, that—you know, the conclusions of that report are under very intense discussion within the committee and the Board at the present time. I can't tell you precisely what the final recommendations will be.

But, the committee, under the chairmanship of Dr. Neal, Homer Neal, of Stonybrook—of the campus at Stonybrook, there's been a very extensive and a very thorough look at the problems there. They've carried on a number of meetings where they've got outside testimony from the whole range of people from 2-year colleges, 4-year colleges, industry, a whole of many of the professional societies. So they've got, I think, the best input from a wide range of the community that they could get.

They are in the process right now of trying to distill that information and to distill it into a few crisp recommendations for the National Science Foundation, and obviously it will be reviewed by the entire Board before we do it.

Mr. **Boehlert**. I have a special interest in community colleges for a lot of good reasons. I would assume that the recommendations might focus a little bit on the need of community colleges. I'm wondering if this budget has any money for aid to community colleges.

Dr. **Schmitt**. Well, do you want to comment on that?

Mr. **Bloch**. Yes, let me comment on that. First of all, let me say that we have a number of programs in the undergraduate area already in the budget, about 50 million dollars' worth. In addition to that, in the 1987 budget, not waiting for the results of the Board report, we have added to that about $13 million in certain specific areas.

None of these are directly associated with 2-year colleges or community colleges. On the other hand, community colleges are eligible, under the College and Science Instrumentation Program, and I suspect—I'm not absolutely sure, but we can check this—that we have made some awards to that.

But somewhere in this whole undergraduate area we have to realize that it's a very broad field, and it's a very expensive field. Somewhere along the line I think we have to draw the line somewhere, otherwise, again, we are not going to spend enough of critical dollars in critical areas if you try to spread it too thin. That's a concern that I have.

Mr. **Boehlert**. Mr. Bloch, has——

Dr. **Schmitt**. If I could just add——

Mr. **Boehlert**. Sure.

Dr. **Schmitt** [continuing]. I want to assure you that that committee is considering that question. It's premature to say exactly what the recommendation will be, but it's not being neglected.

Mr. **Boehlert**. Well, we're waiting with great interest. Mr. Bloch, has the agency decided the subjects to emphasize in the new engineering research centers?

Mr. **Bloch**. As you know, we have gone through a very exhaustive evaluation of the 100 proposals. The 100 proposals are being rank ordered by excellence, and that really determines the subject matters. But the subject matters that came in, amongst the 100 proposals, were really very diverse, spanning all kinds of areas. And therefore, I think we are going to get a good mix of subjects.

Again, out of five new awards—just like out of the previous six—you can't cover all the subjects that you would like to cover. But I am convinced from what I have seen, namely the input, that we will get a very varied subject matter out of the 11 centers once they are in place. I can't tell you right now what the five new subject matters are. We are still looking at that. But we'll let you know as soon as we have made our decisions.

Mr. **Boehlert**. Well, I'm just glad to see the increased attention being paid to engineering at NSF. And I would like the record to know that a colleague of Dr. Schmitt's at General Electric, Nancy Fitzroy, is the president-elect of the American Society of Mechanical Engineers. It shows you how enlightened engineers are these days.

One last question. I know I have an opportunity for others, but I'm just wondering, how are the negotiations going with the Soviets—or negotiations not with the Soviets, but on the restrictions on the use of supercomputers by Soviet bloc scientists? Now, that's a hot subject, I know. Where are we right now?

Mr. **Bloch**. Well, yes, it's a hot subject. And the negotiations change on almost a daily basis. I'm kind of, I must say, I'm frustrated that we have not brought them to a conclusion. But we have not—and let me explain for a minute where we are and what some of the issues are.

First of all, what the Foundation thought and what the university supercomputer centers management thought would be proper and would be the right thing to do is that the Government takes on the responsibility for visas, like it always does, and for visa restrictions if there is a restriction on a particular individual. That's very proper, and the Government should enforce that and not ask the universities to enforce it. So that's point No. 1, and there is no problem with that.

Point No. 2, we thought it would be very advisable to have an exception procedure so that if an individual wants to come over here who has been turned down, he has a way to appeal. And also the principal investigator with whom he collaborates here in the United States has a way to essentially assess and speak his mind how important the contribution of that particular foreign national will be to the total program. And again, the Government can deny that in the end. The Government is in charge of that one. But we want an exception procedure. That's where one of the hangups is; that the exception procedure is being considered by some parties in the Government as not being in the interest of the United States.

The third point that we wanted to make was that for those students that are studying in the United States, have been admitted to the United States, take courses on supercomputers, that as part of their course work that their access to supercomputers is unrestricted. And by unrestricted let me mention right away that doesn't mean hours and hours, and days and days on the supercomputer. That means minutes, at best, OK? And that's a hangup that we have.

And the fourth point that we made is that the normal procedures that apply for access to supercomputers—namely passwords, security of the physical supercomputer center itself, the security of the manuals that describe the supercomputer, and so forth—that that was adequate for essentially enforcing these considerations. And I think there is agreement on that. So we are hung up on two, what I consider, kind of minor points.

Mr. **Boehlert**. Is progress being made? I mean, do you think we're getting closer off——

Mr. **Bloch**. If you ask me on Monday I think yes and on Tuesday I think no. I would say right now very little movement. It's about the best way I can respond.

Mr. **Boehlert**. Thank you, Mr. Chairman. I'll get back later.

Mr. **Walgren**. Thank you, Mr. Boehlert. Mr. Lujan.

Mr. **Lujan**. Thank you very much, Mr. Chairman. I'm interested in—perhaps it would be a policy change, perhaps the policy is in place now, but I was looking at the section entitled, "Leveraging of Federal Dollars." And as we look on down the line, as you know, the policy of this administration is cost sharing wherever we can, user fees wherever we can. You know, at first thought some times one thinks it's pretty heartless, for example, if you're drowning out in the middle of the ocean and the Coast Guard goes out and gets you. You're going to have to pay a fee according to, you know, what we're looking at now.

But upon examination you think well, that's not so bad, because if you break down in the middle of the highway, you're going to have to pay someone to come and get you. So, maybe there's some justification to looking at things like that.

And in that regard, as far as the National Science Foundation is concerned, you've mentioned some matching dollars at the engineering centers, you know, what the industrial support that comes in. But more specifically, in user charges--for example, the charging for publication, in charging an adequate amount. The charging for use of time at—I don't know if you operate all of these, but, you know, like VLA, and ARECIBO, and all of those, maybe the Antarctic Program or the atmospheric research at Boulder.

Do you charge people to use those, and are those fees in keeping with the costs?

Mr. **Bloch**. No, we're not charging for publications. We are not charging for the use of any facilities that we sponsor unless it is essentially for proprietary kind of research which is not shared with anybody else. As long as it's open, as long as it's shared, we are not charging for it.

For instance, we just looked at a case of the magnetic lab up in Minneapolis—at MIT where that came up. So we are not charging for that. I don't think we should, by the way, because many of these joint, cooperative kind of efforts between industry, in that particular case, and university investigators, I think are to the benefit of both, and who knows who gains more from it. It's hard to say.

So the leveraging that I addressed in my written testimony is a little bit of a different kind of an animal. It's essentially, deliberately structuring a program in such a way that industrial participation or State participation—it doesn't have to be industrially, it could be State or local government participation. Or some times the participation from the funds of the universities make that program a stronger program, because the benefits from the program essentially come back not to just the universities, but to all the participants.

We have made a deliberate effort of structuring programs in that particular way. Maybe Dr. Moore would like to say a couple of things on that.

Dr. **Moore**. I would just add to the list of things where we do some kinds of cost sharing. You've mentioned the engineering research centers. I think Erich already mentioned the College Science Instrumentation Program, which has been extremely successful in attracting matching support and requires matching support.

Also there's been a good deal of industrial participation in the supercomputer centers. And one other program that I might mention is with regard to discounts on instruments that are provided, that are bought by NSF grants to be used in university laboratories. We have a very aggressive program to develop a system of discounts with manufacturers so if an instrument is required by a grant, it could be bought at a special price.

Dr. **Schmitt**. If I could comment on that also, Mr. Lujan. The fact—the National Science Board does have a committee in operation right now called Leveraging NSF Funds, under the chairmanship of Dr. Annelise Anderson, who is on the Board from Hoover Institute.

And the committee is due to report again in March. We have a large number of our reports due in March. And they have been examining the implications of the requirements for matching support from industry, universities, State, and local government. They've been looking at the forms that this leveraging take or could take at NSF, or whether some forms are more appropriate than others, and what the underlying objectives are. So it's a comprehensive look at the whole issue of leveraging and why you do it. There are several different reasons for using leveraging in NSF programs, and we will have a complete report on that within a month or so.

Mr. **Lujan**. Yes, and I congratulate you for all of those efforts. And I think they're excellent. One of the recommendations that I would make to the subcommittee and full committee is that we look for user fee-type opportunities, cost-sharing opportunities, and things like that.

You know, sometimes—and this is not meant in any way to be a criticism of any of the agencies that we deal with—but sometimes we're very comfortable with this sort of thing and we make up reasons why we shouldn't. You know, that poor guy that's drowning out there in the middle of the ocean, if we save him, he'll go back to his job and pay taxes and so that's going to be good for the whole country; those kinds of reasonings.

And I would imagine that the subcommittee would be—at least some of us will—be going back to you to examine some of those opportunities. There's no reason why we shouldn't charge for publications, for example. We're faced with that in NOAA, when we're talking about commercializing the satellites. Well, you know, what about the weather on the news, that's a public service. You know, why shouldn't the television stations pay for it if they're going to benefit by something like that.

So we'll be getting in touch with you for some of those suggestions. It's not a criticism of the budget because I'll tell you that I would support the full—and I've told you before—the full $1.685 billion of funding. But I think that's the way that we can look at, one, enhancing the budget for NSF, or at least if anyone comes along with some bright ideas of cutting your budget that we have a way to make those up.

Mr. **Bloch**. We'll be glad to discuss it with you.

Mr. **Lujan**. Thank you.

Mr. **Walgren**. Thank you, Mr. Lujan. Mr. Cobey.

Mr. **Barton**. Mr. Chairman, could I be yielded to for one question?

Mr. **Walgren**. Certainly.

Mr. **Barton**. I appreciate the opportunity. I'm not on this subcommittee, but as I'm trained as an engineer and have an interest in this subject, I wanted to sit in on it.

I'm going to make a comment and then ask a question. I want to applaud the National Science Foundation Board for trying to branch out and get more universities involved. The engineering research center project I think is an excellent project. There are a lot of other projects.

I have a list before me of the top 50 universities in terms of academic R&D support in 1975, and the top 50 list in terms of 1984, and there are not many changes on the list. One reason is because the top universities—Johns Hopkins, MIT, Stanford—are tremendous research facilities, and we should fund them to a large degree.

The concern I have is twofold. First, that perhaps there are other developing universities that should begin to get a larger share of research dollars, and, second, many of the universities that we are funding at a tremendously high level, because of their programs they attract a large number of international students. And perhaps we're educating the world with our Federal research dollars instead of educating our own American students.

If you'd care—any of you gentlemen care to respond to that?

Dr. **Schmitt**. Yes. Well, both Mr. Bloch and I will respond to that. The issue is an important one. And as a matter of fact, it is another one that we are examining in our committee structure of the National Science Board. We have a committee called Research Excellence and Breadth of Research Participation, which is exclusively charged with looking at what NSF's policy and position should be with respect to the breadth of participation in frontier research.

That committee is, in fact, again going to have this report ready in March. But in the interim, one of the programs that it looked at was the EPSCOR Program, a program that the Foundation has supported in the past. And, as a matter of fact, an interim result of that committee's examination was to report favorably on the effect that that program had. It's a program which is essentially aimed at aiding regions, schools, that have not participated heavily in the National Science Foundation program in the past, to get in a position to do so. It's had a very beneficial effect they believe, and that fact, that interim result of that committee, is reflected in the 1987 budget.

Now, Mr. Bloch, you may want to add to that.

Mr. **Bloch**. Let me add to Dr. Schmitt's comments. The question you're raising is a very good one, and it is one that has preoccupied us for many months, maybe even longer than that. We are taking that issue very serious. And, for instance, in the EPSCOR Program, which was just mentioned, which is an experimental program to stimulate research universities in certain States that don't participate in the list that you just mentioned, to come up to that level where they can be participating. That program has been in existence for a while and we are continuing it. In fact, we are increasing it in the 1987 budget.

In addition, you should know we are protecting certain programs from the Gramm-Rudman effect in 1986, and EPSCOR happens to be one of those programs; so are the minority and the women programs that I mentioned before, so that we don't take 4.3 percent out of that.

But you should also understand, and I would like to show you that in a graphic kind of a way, in a viewgraph, the distribution problem—namely the participation of universities, the participation of States—is not quite what you would gather if you just looked at the first 50 and discuss with you for a minute. I think the staff has some charts that could be distributed to you, and I would like to lead you through these particular charts.

If you look at the first one, it's essentially—the charts are always oriented the same way. You have dollars per whatever there is, and then the various States on the horizontal. This first chart is by State. If you just divide NSF dollars by the number of States, and you ask yourself how many R&D dollars go to each State, you see essentially the picture that you see here. And you see it's bunched to the left a few States are standing out, and then it dribbles off to the right.

Some of the ones that are shown in black are, by the way, the EPSCOR States, and that we are addressing very specifically, and this shows you why we are addressing those; because they are really at the low end of the totem pole. Now, that's one way of looking at it. That takes the total budget and divides it by the number of the States.

If you turn to chart No. 2, you see a slightly different story. And this essentially takes into consideration population. And this is essentially the dollars of the National Science Foundation, research dollars of the National Science Foundation per capita by State. And you see a slightly different picture. It's no longer as bunched as it is, and it doesn't drop off as fast as it does. So essentially, dividing by number of States is not necessarily the best indicator.

Per capita is a better indicator. Again you see the EPSCOR States in black.

If you turn to chart No. 3, you see a different kind of a story; namely the dollars per academic science and engineering population by State. And you see essentially the same story continues. You see a much broader kind of a distribution than you saw on chart No. 1 and also somewhat of a more equal distribution than you saw on chart No. 2. And some of the States are changing roles essentially. And obviously, unless you have scientists and engineers in a State, you can't perform very good research or you can't perform research.

If you turn to the last chart, it's essentially one where we are dividing the number of dollars by the number of high rated proposals per State. And you see essentially—and you would think that would be a very good match. The point I want to make on this chart No. 4, that between chart No. 4 and chart No. 3, essentially the difference is not as great as you would think it is.

Mr. **Boehlert**. Mr. Bloch, one gets the impression that you expected this question. [Laughter.]

Mr. **Bloch**. Well, Mr. Boehlert, I've been asked that question over the last few weeks a number of times, so I'm prepared. Thank you.

[The material referred to follows:]

NATIONAL SCIENCE FOUNDATION ANALYSIS
GEOGRAPHIC DISTRIBUTION OF AGENCY FUNDING

The following charts are all based on the relative distribution of 1983 R & D funds of the National Science Foundation. The measure chosen to distribute these funds differs; the first two are commonly used to measure the relative equity of NSF's funding patterns against some standard other than science. The fourth, and last, is a presentation of the impact of NSF's standard for research excellence on its funding distribution. The third, the number of scientists and engineers, is an attempt at a halfway measure.

The substance of the analysis displayed by Charts 2, 3, and 4 is that when viewed aganist a number of different, but significant parameters, the distribution of NSF funding is clearly more equitable than Chart 1 would lead one to conclude. The data on Charts 2, 3, and 4 show that almost half of the states exceed or meet the average funding level indicated. Further, in many of those states where funding levels are significantly below the average, NSF is making a concerted effort to assist in the improvement of the scientific and engineering research and education infrastructure through such activities as the Experimental Program to Stimulate Competitive Research and enhanced support levels for undergraduate institutions in both the research and education activities of the Foundation.

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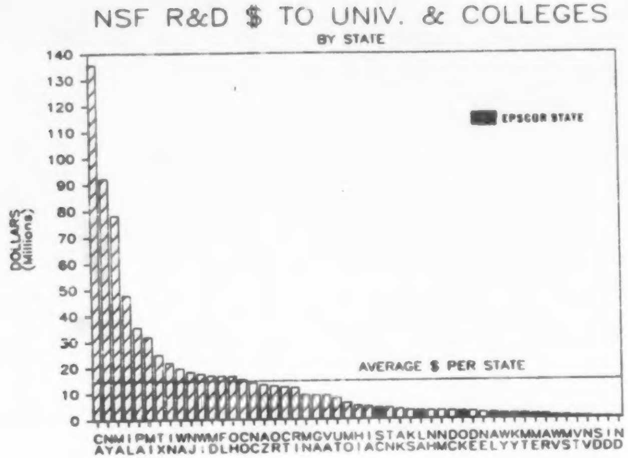
CHART 1 of 4

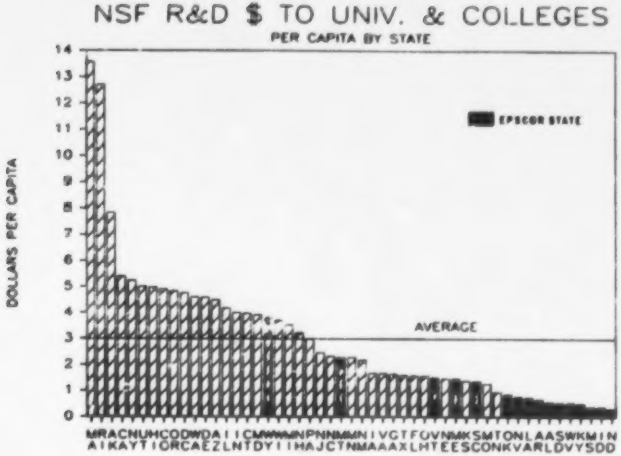


NSF R&D FUNDING TO UNIVERSITIES AND COLLEGES BY STATE

- States are arrayed in order of receipts of 1983 NSF R&D dollars to universities and colleges.
- California, New York, Massachusetts, and Illinois are the high recipients.
- EPSCOR states represented by solid bars.

SOURCE: National Science
Foundation Feb. 1986

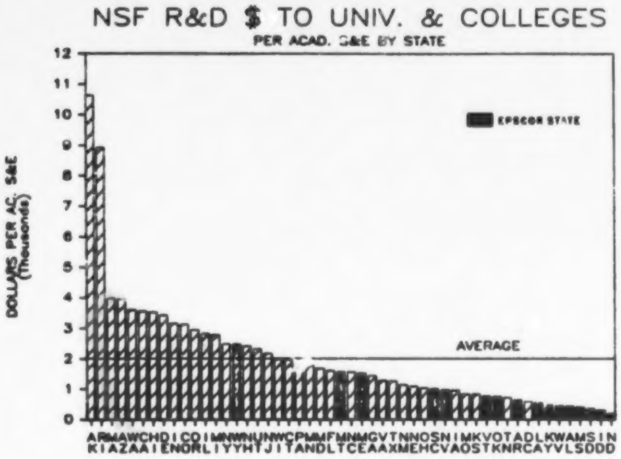
CHART 2 of 4



NSF R&D FUNDING TO UNIVERSITIES AND COLLEGES PER CAPITA BY STATE

- o Same NSF funding data divided by each state's population. Plotted in in descending order of per capita state funding.
- o The high states are Massachusetts ($13.56/capita), Rhode Island, Alaska, California, New York, Utah, and Hawaii.
- o States represented by solid bars are the states being assisted through EPSCOR.
- o Twenty-two states exceed or meet the average including such states as Delaware, Arizona, Wyoming, and New Hampshire.

SOURCE: National Science
Foundation Feb. 1986



NSF R&D FUNDING TO UNIVERSITIES AND COLLEGES PER ACADEMIC SCIENTIST AND ENGINEER

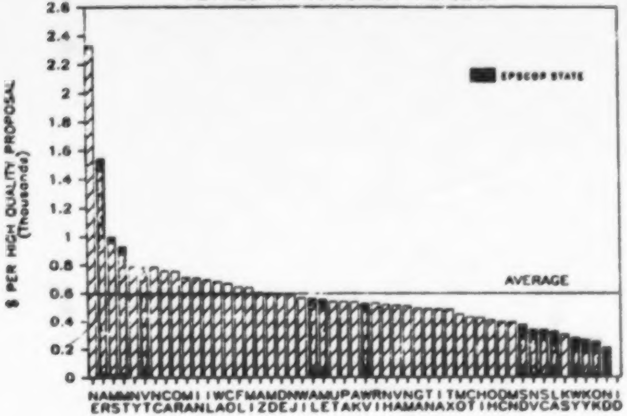
- NSF R&D funding divided by the number of academic scientists and engineers in each state, arranged in descending order.
- The high states are Alaska, Rhode Island, Massachusetts, and Arizona.
- States represented by solid bars are the states now being assisted through EPSCOR.
- Twenty states exceed or meet the average including such states as Colorado, Minnesota, and Utah.

SOURCE: National Science
Foundation Feb. 1986

CHART 4 of 4

NSF R&D $ TO UNIV. & COLL. BY STATE

PER INDEX OF HIGH QUALITY PROPOSALS



NSF R&D FUNDING TO UNIVERSITIES AND COLLEGES DIVIDED BY NUMBER OF HIGH RATED PROPOSALS PER STATE

(PROPOSAL QUALITY INDEX)

- NSF R&D funding per state divided by a sample of high rated proposals from each state in the years 1980, 1981, and 1982.
- The chart shows that, in general, NSF's allocation of R&D obligations to academic institutions is proportional to the highly rated proposals coming from a state.
- States represented by solid bars are the states being assisted through EPSCOR.
- Nineteen states exceed or meet the average including such states as Nebraska, Arkansas, Mississippi, Montana, Florida, and North Carolina.

SOURCE: National Science Foundation Feb. 1986

Mr. **Boehlert**. Will my colleague yield just one second?

Mr. **Barton**. Well, I'd be happy to yield and I want to follow up. You didn't relay the research dollars as related to institutions that have a disproportionate share of international students.

Mr. **Bloch**. No, I didn't. But let me—I'm sorry, I didn't address that question. I apologize. But let me say something on that. That's an issue that we have been looking at also. It's a two-edged sword, let me say that. If it weren't for some of the foreign students that are coming in and that are staying here, that are getting their Ph.D. here, they're getting educated here, and then joining the work force either in academia or in industry, I think we'd be in deeper trouble than we are. And I can speak of that from my industrial experience, and I know Dr. Schmitt can speak to that particular point very well.

Because the drop off in American Ph.D. candidates over the last few years has been very significant, especially in the areas like computer science, in areas like electrical engineering, but also in some of the other science areas, so we're depending on that work force.

My concern about that is it's one that is not under our control, and therefore it can be cut off tomorrow morning because of political consideration—just think back about Iran a few years ago where that actually happened. And that's my concern. And we need to do everything possible—and the Foundation's programs are aimed at that—to make sure that we are attracting more American citizens to the Ph.D. track. It's especially in the Ph.D. track where that dropoff is that sharp.

And the reason for it is very simple. It's an economic competition. How much can you earn in industry versus how much do you have to spend to get your Ph.D. That's essentially the equation.

Mr. **Barton**. Well, I'm not suggesting that we shouldn't educate the brightest students in the world. I think they come to the United States because they can get the best education. Hopefully, after they get that education they will stay in our country. But it does appear that some of the research dollars do not go to universities that do not have a high proportion of international students, and that is just a concern. I'm not making any accusations. It's simply a concern.

I'll be happy to yield back the balance of my time to Mr. Boehlert.

Mr. **Boehlert**. I just have two quick questions. One, do we have any figures on the percentage of foreign born students who are educated here, who remain here?

Mr. **Bloch**. Yes.

Mr. **Boehlert**. It's a very high percentage, isn't it?

Mr. **Bloch**. It's a very high percentage. It's about 60 percent, OK?

Mr. **Boehlert**. And, Dr. Schmitt, wouldn't American industry have some real problems if they didn't stay here?

Dr. **Schmitt**. Absolutely. I would like to emphasize as strongly as I can the statement that Mr. Bloch made. American industry today, the industrial laboratories of this country, would be in deep, deep trouble today were it not for foreign nationals that we have been able to employ who have come to this country and have stayed in this country, gotten their Ph.D.'s here.

If you would come to my laboratory and walk through the hallways, you would see a fairly significant proportion of foreign Ph.D.'s that we have hired. Without that source of talent over the past few years, I think American industry would be in deep trouble today.

Mr. BOEHLERT. And doesn't—and then I'll be quiet now—but doesn't this point up the urgent, pressing need to get the people earlier and interested and on the correct career path? They do so much better at this in the nations abroad than we do right here. So math and science education upgrading at the elementary, secondary level, and then more money for doctoral work, for fellowships, and all that sort of thing. I mean, that's critically important, isn't it?

Dr. SCHMITT. Yes, it is, Mr. Boehlert.

Mr. BLOCH. Can I just comment on your point? Obviously it's very critically important. And, by the way, one of the other things we are doing in 1986, we are protecting the number of fellowships. We're not letting those go down by 4.3 percent. We're not letting the stipend go down by 4.3 percent. We're keeping it at the level it is.

We're taking the 4.3 percent because it's a line item and we have to take it out of there. We are taking it out of the education allowance which will hit the universities, OK. But we are not reducing the number of fellowships or the stipend in that particular area for exactly that reason that you're pointing out.

Mr. BOEHLERT. I think one of the most exciting trends from a layman's point of view looking at the overall field is the increase in the percentage of women going into engineering, for example. And who knows, they might end up president of a national organization.

Mr. WALGREN. Thank you, Mr. Boehlert. Mr. Cobey.

Mr. COBEY. Thank you, Mr. Chairman. I appreciate you coming and testifying. I come from North Carolina, and looking at these charts and realizing that I have North Carolina State University, the University of North Carolina at Chapel Hill in my district, and also Duke close by, I didn't realize that we were below average in most of these categories. I thought, in fact, we were probably above average, and maybe we need to follow the lead of our basketball team at the University of North Carolina. We may need to move up in these rankings, so we'll see what we can do to move up.

I wanted to not ask a question, but to make a comment that I think the lack of basic research probably addresses a general problem that we have in our country, that we have gotten to the stage where everybody expects instant success and instant gratification, and we aren't looking at the long term like we should.

We're in a sense in so many areas eating the seed corn of this country. And I am one that voted for Gramm-Rudman because of the disasterous deficit problems that we have in this country or that could create a deficit. But if we do our job in legislating, hopefully we can protect basic research and even enhance it, not just this year but in years to come. Because I view it as a tragedy that we would let it be cut by Gramm-Rudman, not do our job.

And I probably reflect the general thinking on this committee not just because maybe the fact that we have research institutions and research in our districts, but that there are certain things that are absolutely critical that our Federal Government do. And one of them is basic research.

And I want you to know you have my commitment. I'm sure I speak for the rest of the people on this committee to do whatever we can do to legislate and not allow these meat cleaver type approaches to budgeting to come into effect. We can move toward balancing our budget without eroding our commitment to basic research. In fact, we need to enhance it, as you have said.

Mr. Bloch. Thank you for your comment. Dr. Schmitt would like to comment.

Dr. Schmitt. I simply want to point out, Mr. Cobey, that in the fourth chart North Carolina is number seven, and it is above average, and I congratulate you on that.

Mr. Cobey. I noticed that, too, so at least we're well thought of. And the work we're doing is well thought of, so——

Mr. Bloch. No, you're doing well. It's not only well thought of.

Mr. Cobey. Right. Thank you.

Mr. Walgren. Thank you, Mr. Cobey. Mr. Wirth.

Mr. Wirth. Thank you very much, Mr. Chairman. Mr. Bloch, we're delighted to have you back again, and I appreciate the difficult task that you have at a time that we're looking at Gramm-Rudman and all of the budget constraints on the one hand, and on the other a so well understanding of the need for us to be making the kind of long-term investment that NSF is doing in the future of the country and the economy. You have a very difficult job.

It reminds me of thinking about talking to you this morning of Harry Truman, remember, after the Second World War. People were coming to him, and how adapt the country's economy to a—from a wartime to a peacetime economy. And they came in and they said Mr. Truman, on the one hand you have to do X, Y, and Z, and on the other hand you have to do this, and he said dammit, give me a one-armed economist.

I think related to this on the one hand, we certainly have to be extraordinarily careful under the constraints of Gramm-Rudman, but on the other hand have some very significant long-term investments that we all have to make together.

So it seems to me that it therefore becomes absolutely incumbent upon all of us to do the best job possible to manage the scarce resources that NSF has, which brings me to the thrust of my questions related to the phase 1 research center concept and then the phase 2 supercomputing centers which you all are setting up.

The thrust of the question, Mr. Bloch, is as follows:

On the one hand, we have a number of university centers which have been designated by NSF now as phase 1 research centers, which have put their own money up for the building of a supercomputer, made that kind of investment. That is all well and good going on. But on the other hand, we have the phase 2 centers which for the most part do not have the investment made, do not have the supercomputer there. And you're going to be equipping those phase 2 centers with supercomputers that already exist in a phase 1 center, as in my backyard of Colorado State University.

And you're spending duplicate money, as I understand the situation, and you can correct me if I'm wrong, but it's spending duplicate money to build five phase 2 centers where some phase 1 center technology already exists. Phase 2 centers will then absorb about $10 million each over a 5-year period of time. Phase 1 centers get phased out.

Now, does this make sense in an era of Gramm-Rudman in which we have, again, very limited resources in which we have to shepherd those resources as carefully as possible, and does it make sense in the face of what we've come to try to accomplish in terms of a better cooperation between the public sector and the private sector?

It's difficult for me to explain to individuals why this kind of duplication would be going on. How do I explain that to Colorado State University?

Mr. BLOCH. Well, let me—you're asking a very good question, and in fact you're asking a number of questions and I really need to speak to it at length. First of all, you should understand—and I don't think you were here when I mentioned it before—that in 1987 we are not going to establish any new phase 2 centers. We established four so far, actually five, one is an experimental center. You can count it in or count it out, it doesn't matter.

We established those and those we will concentrate on to make them work efficiently and effectively.

Mr. WIRTH. Right there, let's not duck the question in any way, shape or form by suggesting that we've established these four——

Mr. BLOCH. No; I'm not ducking the question.

Mr. WIRTH [continuing]. Centers and we're not going to establish anymore. The question is, are we establishing four or five, putting a new investment in those four or five, which investment already exists elsewhere? Does that make a lot of sense——

Mr. BLOCH. I'll get to that. I just wanted to give you some background.

Mr. WIRTH. OK.

Mr. BLOCH. It was not to duck your question at all.

Mr. WIRTH. I'm not suggesting ducking. I just want to make sure that we're doing this in a very rational and thorough progression.

Mr. BLOCH. I'll try to keep it on that level. When we established the centers because there was a need for supercomputer cycles and that capability. I don't believe for a minute that the phase 1 centers will not be kept busy even though the five centers are being established now. Because even with those centers, I think we have a shortage of cycles available to the people that need it.

Just look at the way we built up over a very short period of time the usage of both the phase 1's and the phase 2 centers. That's point No. 1.

With regard to Colorado State, in particular, you should understand that in 1986 it's being funded at about a $2 million rate, and for 1987 about $2.3 million are undesignated for unique kind of capabilities. Not all the centers that we are establishing have the same capabilities that some of the other centers have. And we will lean on phase 1 centers wherever we can and wherever we have the money for unique capabilities. That's point one I wanted to make.

Point No. 2, I'm pretty sure that Colorado State started that center, and it started it before the National Science Foundation started their centers——

Mr. **Wirth**. They had great vision in Fort Collins.

Mr. **Bloch**. Well, they did, they did, and they should be congratulated for it. But I also think that they had a business plan of how to keep that center busy. And it's true that the National Science Foundation bought some time from these centers, and buying some time from that particular center, which probably they didn't know about when they first started, but these things happen.

Second, I know for a fact that if you just look at industry, that there are many requirements for supercomputer cycles. And I don't think any of the supercomputer cycles are going begging today. I really don't believe that. Now, I'm not absolutely sure because I haven't made a survey of it. So I don't think that Colorado State or any of the other phase 1 centers will have a problem getting a full usage of their capability. The second point I wanted to make, not quite so that Colorado State and the other phase 1 centers essentially put their own money in and the other phase 2 centers are not. That's not quite true.

Because for every dollar that we are putting in, the National Science Foundation is putting into Illinois and the San Diegos of the world, and so forth, they are putting in 40 cents from either their own funds or from State funds or from industry kind of funding. So we are leveraging that particular program.

And the last point I want to make, we have been working with the phase 1 centers very intensely to make sure that we utilize their capabilities wherever we can. The reason why we are to phase 2 centers, we paying less on the phase 2 centers per hour than the other centers—it's about $300 versus $800 on the average. It varies from center to center. So it has to do essentially also with the cost to the National Science Foundation. And the more—the less the dollars per hour, the more hours we can afford with the limited budget that we have.

But it's a more complex story. And I assure you that Colorado, plus the other centers, we have been looking at it, we have been working with them, we are supporting them as much as we can. Obviously we're going to phase them out over time. That was the intent as our centers are coming onstream.

By the way, we have some delays in one of our centers, and that makes money available for some of the phase one centers, to fill the gap that we thought we could fill from one of our own centers. And that's why you see the 1986 dollars into Colorado State and the 1987 dollars into Colorado State.

Mr. **Wirth**. Let me——

Mr. **Bloch**. But it's not black and white is what I wanted——

Mr. **Wirth**. Well, it's a little bit of button, button, who's got the button. I appreciate your answer. Let me come back with some specifics if I might, Mr. Chairman. Is it the case that when you establish the five phase 2 supercomputing centers that Colorado State University and other institutions that already have supercomputers did not meet the qualifications that you thought were necessary for phase 2 centers?

Mr. **Bloch.** No; it didn't meet the requirements that we saw that we needed in terms of total cycles, because they have their own programs which they are running on these centers. Not giving a center to the National Science Foundation——

Mr. **Wirth.** But they had applied to be a phase 2 center, feeling, of course, that they, therefore, could meet whatever requirements you were setting up. Again, I'm back to the question, we already have this capability, they're presenting the request to get to, you know, to become a phase 2 center.

Does this mean that they did not meet your requirements——

Mr. **Bloch.** I'm not sure that in your particular example of Colorado State that they applied for a——

Mr. **Wirth.** I do believe that they did, yes, sir. Yes, they did. Your staff agrees.

Dr. **Connolly.** Colorado State University did apply for a phase 2 center.

Mr. **Wirth.** Yes.

Dr. **Connolly.** That was—it did——

Mr. **Wirth.** You might identify yourself for the record. You might want to come up and join us, if that's all right, Mr. Chairman.

Mr. **Walgren.** No, I'm enjoying this. [Laughter.]

Dr. **Connolly.** Colorado State University did apply in that competition. We had 22 proposals that came in. It was a very, very competitive process. And through a very lengthy and thorough review, we determined that we were going to fund the top five, and that was what we had the budget for.

Mr. **Wirth.** Some of them had no supercomputer capability at all. They were starting——

Dr. **Connolly.** That's right. Some of them were starting right from scratch. Now, it is true that Colorado State has a lot of experience and we've taken advantage of that experience. Their machine at the present time is not at the same level as some of the machines that we have at the phase 2 centers.

Mr. **Wirth.** That may be built in the phase 2 centers that aren't up to that level, is that right?

Dr. **Connolly.** Well, no. There are—we have four phase 2 centers currently with machines online. Three of them have CRAY-X-MP's, which are—CRAY-X-MP's is roughly seven times the capability of the Cyber 205 that Colorado State has.

Mr. **Bloch.** Could I just add something to that? I would be surprised, really surprised, if I would find out that these supercomputer centers that came into existence on their own—like Colorado State, like Purdue, and a few others—would not be fully—Minnesota—would not be fully occupied and fully used.

In fact, over the last couple of years we went out and bought some time from some of the commercial centers, like Boeing, for example, because we couldn't get enough time from any of the existing centers. So I would be very surprised because I see the usage of it going up, I see industry asking for time on some of the centers on and off.

Mr. **Wirth.** We did that—I understand. But just let me make sure that I understand. It was your judgment that scarce taxpayer dollars would be better spent building from scratch in five new centers, rather than building upon existing capabilities; whether they be at Purdue, Minnesota, or CSU, is that correct?

Dr. **Connolly**. That's correct.

Mr. **Wirth**. And does the taxpayer save money that way? I mean, is that pretty well—you know the technology a lot better than I do. I just listen to taxpayer complaints about dollars on something that was——

Dr. **Connolly**. Yes; the technology changes very rapidly. And what you see in the computer business is that you get—this year you get many more cycles per dollar than you did last year. But you have to continuously stay at the state-of-the-art, and that's our plan for the phase 2 centers, that you stay——

Mr. **Wirth**. Well, how far along will they be state-of-the-art? Are we going to expect phase 3 to kick in? Should we start anticipating that? It seems to me that perhaps we're in a situation where Purdue or Minnesota or CSU are getting penalized for having the vision of having done a supercomputer to begin with. And maybe they ought to be thinking about phase 3 when the cycle comes around that phase 2 becomes obsolete.

When are those proposals going out?

Dr. **Connolly**. Well, it's our intent that if the budgets allow that we will keep our phase 2 centers at the state-of-the-art continuously. As the machines become obsolete, we will replace them.

Mr. **Wirth**. Why couldn't that have been done, then, with phase 1 centers?

Dr. **Connolly**. It could. And some of the phase 1 centers, including Colorado State, did propose that in the competition. The Colorado State proposal, as I recall, was for, I believe, was for something like $43 million over 5 years, and it included a Cyber 205 to be upgraded to an ETA 10 machine in the fifth year. Now, so it did include that upgrade in their particular proposal. And it was part of the competition.

And after a very—it wasn't just my judgment or my staff's judgment, but after a very thorough peer review, we determined which we felt would be the best for science in the country, namely the top five that we finally awarded.

Mr. **Wirth**. Let me ask you a final question, if I might, about what's going to happen in terms of the phasing out of funding or of long-term funding. You said, Mr. Bloch, you're going to phase out the funding of the phase 1 funding for all of these centers, is that correct?

Mr. **Bloch**. Well, what I said was that the phase 1 centers are essentially being funded a year—have been funded on a year-by-year basis. We didn't have a commitment to fund over 5 years or something like that, OK. And that as the user centers are coming up and taking up the load, we would hopefully need fewer and fewer of the phase 1 centers. And obviously the one that we are phasing out first are the ones that are the most expensive ones.

Mr. **Wirth**. And which are—and is CSU among the most expensive ones? Is that the——

Mr. **Bloch**. Well, I wouldn't—I don't know. I wouldn't want to say that. I'm just trying to assure you that we go down a rational kind of a path. I don't know how the centers stack up. Dr. Connolly might be able to say.

Dr. **Connolly**. At the current level of funding, yes, you're right, Colorado State is one of the more expensive. It's not the most expensive, but it's certainly not the cheapest.

Mr. **Wirth**. And what happens to the funding on this for 1987 in your plans?

Dr. **Connolly**. As Mr. Bloch pointed out, we have $2.3 million designated in the 1987 budget to continue to provide resources in a phase 1 like mode, although we won't call it phase 1, we'll call it the resource centers.

Mr. **Wirth**. You mean to the research centers in phase 1, right?

Dr. **Connolly**. Well, there will be a competition for resources that aren't being provided by the phase 2 centers.

Mr. **Wirth**. And when will that competition be getting——

Dr. **Connolly**. Later on this year. Some time during the summer of 1986.

Mr. **Wirth**. And there'll be $2.3 million in the, is this correct, in the competition for existing phase 1 centers?

Dr. **Connolly**. If the 1987 budget is approved, that's——

Mr. **Wirth**. The 1987 budget as requested by the President's budget message, is that correct?

Dr. **Connolly**. That's correct.

Mr. **Wirth**. Fine. Let me also, just as a final and more parochial note suggest that the phase 2 centers, you know, tend to be bereft of any mountain environment if you were to look at this. If you were to look at where the phase 2 centers are located—and we do like, as you were suggesting earlier in your exchange with the gentleman from North Carolina, Mr. Bloch—to assure that the resources and perspective of the National Science Foundation is spread across the country.

And I wanted as a closing comment to encourage you as well to be aware of this dramatic growing and extremely capable area of the country represented by CSU and other institutions.

Mr. **Bloch**. Well, we have a couple of institutions up there ourselves, like NCAR, and I want to remind you of that.

Mr. **Wirth**. I'm aware of that. I'm looking at the supercomputer side.

Mr. **Bloch**. Right. Well, Dr. Connolly should comment on that one.

Dr. **Connolly**. Well, there are actually six supercomputer centers funded by the National Science Foundation. One of them is part of the National Center of Atmospheric Research in Boulder.

Mr. **Wirth**. I am aware of that as well, and we're aware of the concerns that you have had, Dr. Bloch, in the NCAR center and keeping that funding going and the extremely difficult time you're having there under current budget cuts. That's a matter of other discussions that we'll look forward to having with you.

Mr. **Bloch**. We're not all bad.

Mr. **Wirth**. I wasn't suggesting that in any way, shape or form. On the one hand, you do a very good job. On the other, you just don't spend enough money in Colorado. I have, if I might, some correspondence which I would like to include in the record at this point.

Mr. **Walgren**. Without objection.

[The correspondence and statement from Colorado State University appear in the appendix.]

Mr. **Wirth**. Thank you very much, Mr. Chairman. And, Mr. Bloch, I appreciate your concern and interest, and we look forward to working with you.

Dr. **Schmitt**. Mr. Wirth, could I make one quick comment? Before you came in, Mr. Bloch showed a number of charts showing the distribution of NSF expenditures in various States in four different ways. And Colorado is above average in every one of these four charts.

Mr. **Wirth**. You and I would agree that it's better to be rich than poor.

Dr. **Schmitt**. Right.

Mr. **Walgren**. Thank you, Mr. Wirth. Let me touch on a couple of points before we close. Those charts that you did submit, we will certainly include them in the record to the best of our ability, and I think our ability would allow that.

[The charts referred to appear to p. 71.]

Mr. **Walgren**. I'm curious as well with respect to these kinds of distributive views, views on balance of distribution, whether or not we have data on other major Federal research organizations. And my purpose being that inasmuch as NSF has an overall, almost backstopping, responsibility, somehow or other we ought to get similar views of the distribution of the other major Federal research investors so that we can see the overall balance State by State or area by area.

Mr. **Bloch**. Yes; Mr. Chairman, we have looked at that and we have some data. I'm afraid that the data is probably not as clean and as extensive as it is for the Foundation just because we didn't have the access to it. Also you should realize that just taking the raw data from the other agencies might be very misleading. For instance, let me give you an example.

DOE, which has national laboratories, big national laboratories, obviously a national laboratory is in one particular State and that can distort the picture completely. So you really have to sort out some of the data so that you deal with the right data that you want to deal with, and not that you look at the net effect of it. But we have some data and we'd be glad to supply that.

Mr. **Walgren**. Well, perhaps the agency could broaden its question not just looking at itself, but—or the Foundation could broaden the question. And we would be interested in receiving whatever views you might provide on that larger question in view of your responsibilities to be—taking into account the whole of the activity out there.

Mr. **Bloch**. We'll be glad to do that.

[The requested material follows:]

NATIONAL SCIENCE FOUNDATION ANALYSIS

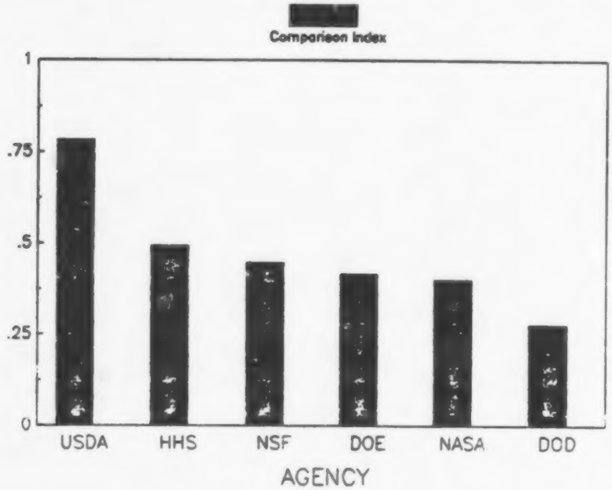
COMPARISON OF GEOGRAPHICAL DISTRIBUTION OF R&D FUNDS TO UNIVERSITIES AND COLLEGES BY FEDERAL AGENCIES

The three attached charts show indices of how closely R&D obligations to academic institutions by state by each of six agencies compare with a) equal state funding, b) state population, and c) the number of academic scientists and engineers in the state.

The data are for FY 1983, and are taken from publication NSF 85-321, "Federal Support to Universities, Colleges, and Selected Nonprofit Institutions."

Chart 1 of 3

Comparison of Agency R&D Funds to Universities and Colleges with Equal State Shares



- **Agencies plotted in descending order of closeness to equal state funding to universities and colleges (1.0 means exact equal state funding).**

- **USDA is closest to equal state funding, presumably because of land grant college programs.**

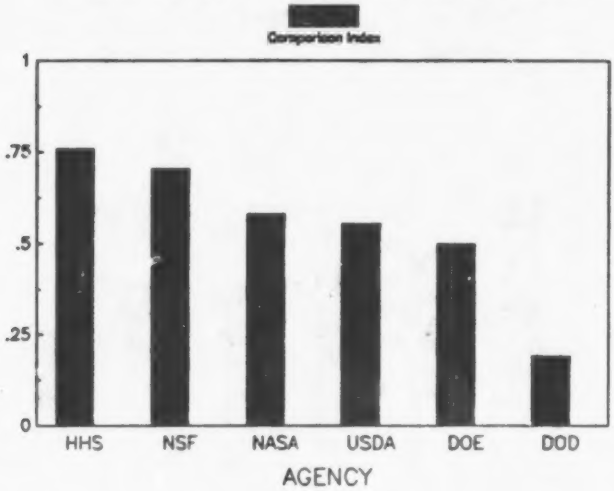
- **DOD is farthest from equal funding, principally because of the inclusion of the Johns Hopkins Applied Physics Lab in the data.**

- **NSF is comparable with HHS, DOE, NASA.**

Source: National Science Foundation
February 1986

Chart 2 of 3

Comparison of Agency R&D Funds to Universities and Colleges with State Population



- o Agencies plotted in descending order of closeness to equal state R&D funding to universities and colleges per capita (1.0 means perfect per capita funding).

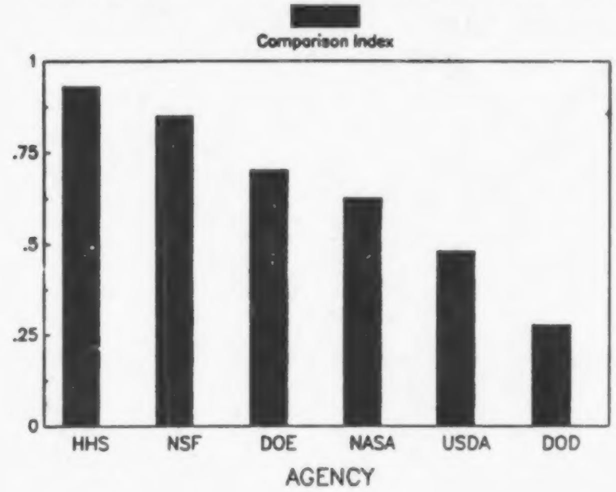
- o HHS and NSF are high, probably because of the location of medical schools and leading R&D schools near population centers.

- o DOD is low because of large centers (APL) and large awards to less populated states (e.g., New Mexico).

Source: National Science Foundation February 1986

Chart 3 of 3

Comparison of Agency R&D Funds to Universities and Colleges with Academic S&E's by State



- Agencies plotted in descending order of closeness to equal state R&D funding to colleges and universities per academic scientist and engineer (1.0 means state funding is exactly proportional to number of academic S&E's).

- HHS and NSF are both highly correlated to state academic S&E's, because they perform the research and develop proposals for new research.

- Inclusion of the Applied Physics Lab at Johns Hopkins University as a university expenditure makes DOD appear lower as in Chart 2.

- USDA would presumably correlate better with agricultural S&E's.

Source: National Science Foundation
February 1986

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Mr. **Walgren**. Also, Mr. Bloch, you mentioned in your testimony that you are continually reviewing this balance between the funding for centers and the other mechanisms of investing money in this area, and particularly the individual project grants.

And the question—the area of concern, and obviously you recognize as well, is that, as I understand it now, 66 percent of our funds will be going into individual project grants, something on that order. That means that 34 percent is going into perhaps what could be described as longer term commitments.

And the concern would be that the more we go toward the centers approach, the more we have committed out your dollars to an investment in almost an institution as opposed to a particular day to day, or month to month, project. And I would be the first to recognize the validity of investing in that mechanism, and yet there's also the concern that we so occupy the dollars with a mechanism of investment that might even have an internal momentum that would require that more dollars be spent proportionally in future years than present years, and that we would then be turning away from the other methods of investing these moneys; in particular, individual support and some of the education functions.

Mr. **Bloch**. Well, let me comment on that. First of all, let me say one thing. That the facilities that you talked about, which is the third—the green area on that particular chart here, is what you really were talking about when you talk about centers and long-term investments, and so forth. And that has stayed fairly stable over the last 4 to 5 years.

What has increased are the group grants, which is the brown area over there. Now, group grants are different. These are a small number of people, many times 15, 16 investigators with instrumentation that essentially serves that particular group to do a particular task. It doesn't have the brick and mortar kind of an aspect that facilities essentially imply. So it's a little bit different.

And what you're seeing there essentially happening, and that's the area that's increasing, what's happening there is essentially that the cost of instrumentation and the complexity of instrumentation, and many times the multidisciplinary nature of the task itself, demands that more than one individual investigator get together and work together on a particular problem.

I think it's driven by the science itself. It's driven by the technology itself essentially. And I think we have to make sure that this doesn't get out of balance and that we are doing the right thing. But in many of the facilities it's also individuals obviously that participate. But in the 64 percent area—it's 64 percent on my chart, your number might be more accurate—on the individual project grants, we have an eye on that to make sure that that does not deteriorate unnecessarily, No. 1, and also not to the point where it really could do some harm.

I hope that the balance we have is the best balance under the circumstances. And, as I said before, a lot of that is driven by the technology itself and by science itself. It's not that we made up our mind that we want more group grants or something like that.

Mr. **Walgren**. OK. You indicated that the emphasis on biotechnology, the computational sciences, and the global sciences, and the minority participation are really going to be accomplished through the various directorates, rather than one only or—particularly, I gather, with respect to the minority participation.

How is that cross-directorate activity coordinated at this point? Is there a structure to it?

Mr. BLOCH. Well, I hope we can do it without much of a structure because structure always implies overhead and bureaucracy. The plan in the budget submission is what does the coordination. As we formulate the plan for 1987, and as we will formulate the plan for 1988, these activities essentially coming up are being proposed by the individual directorate, and then it's essentially the budget office's job to pull it all together so that it makes a coherent kind of a whole. And we will monitor the activities as the year progresses to make sure that we are doing the right things, No. 1, and that we are on plan.

But it's really up to the individual directorates, just like they treat everything else in that directorate, to make sure that they are pressing that particular area itself. So it's not that one needs a big hierarchy or a big bureaucracy to enforce that. We're trying to avoid that for obvious reasons.

Mr. WALGREN. Last year the House-passed bill tried to address the requirement that the President appoint the Assistant Directors at NSF, and we were moving toward giving the Director the ability to make those appointments. That got left out in the conference with the Senate, as I understand it, and was not part of the authorization law that was signed by the President.

Can you give us any guidance on the importance of that element to the long-run future? We understand that now the Directors are appointed, and that's good. And so, we don't face the immediate vacancies that we did two years ago, as I understand it. But I think we have a longer run responsibility to try to get this right, and the question is, What's right in that area?

Mr. BLOCH. Well, what's right is what we proposed last year; namely that the AD's should not be Presidential appointees. And if you remember the reason that I advanced at that time was very simple, that some of these openings were 2 years old and older. Now we're lucky that all of them are filled right now. But I would not want to go through that again, you know, and see an opening like AAEO or MPS or any of them open for years. And I think it's bad management, because the Assistant Director's job is a very—is a more important job than my job because he runs the day to day business of the Foundation, he runs his area, and he's the one who knows of the day-to-day activities.

So, I hope we can get back to that and get that amendment passed. I sure would urge you and urge this committee to include that in your bill. I feel the same way I did last year. It's right that the urgency is not there right this minute, but what about a year from now, what about 2 years from now? And I can't imagine that an organization in industry, for instance, would leave an important job like that unfilled for 2 years. And why should the Government be different?

Dr. SCHMITT. Mr. Chairman, I think we also pointed out last year that NSF does not lack for oversight by Presidential appointees, considering that all the members of the Board—and it would be expected that the Director and the Deputy Director would still remain in that category. So the roles of the Presidential appointees associated with NSF are sufficient to provide that kind of oversight.

Mr. **Walgren**. Turning to the Antarctic Program it's always been a lurking thought that somehow or other that very scarce resources that we put toward NSF are somehow going to support some of the military involvements in Antarctic. And some of us have felt that that more rationally comes out of military budgets which have a lot of room to cover those kinds of costs.

It was my—someone suggested that there was an airplane that we were recovering down there at a certain cost, and that somehow or other some NSF money might be spent on recovering this airplane.

Can you give us a little capsule of how our moneys are directed in Antarctic, and is there any possibility that our research moneys are being used in terms—in a more day to day military support presence than anything else?

Mr. **Bloch**. Well, it's a difficult question to answer. Let me just remind you that the Antarctic Program has a life of its own. It's in a separate bill essentially, not mixed in with research and related or not mixed in with the education budget. So it can be looked at as one isolated kind of an item.

I also have found that there is no tradeoff between the two that people would want to make. So money doesn't move from research into Antarctica or vice versa. If anything, this year we got a hidden kind of an increase in there. You see essentially on the paper it's about a 2-percent increase for Antarctica. Actually it's more than that because a number of dollars that we were responsible for—namely for the ice breaker support, not for the incremental, but for the basic ice breaker support—that responsibility has been transferred elsewhere, and we were left with the money which we now can use to do research and to do the facilities work that we need to so badly do in that particular location.

It's a very fine balance, obviously, and we are doing as much research as we possibly can. It's a very expensive kind of research because of the facility and the logistics problem involved. We're trying to do as much as we can with it. And I think that's understood by OMB, in particular, and I don't think the trade-offs are being made between research and logistics, for instance, or anything else.

We are trying to recover that particular airplane because that seems to be, believe it or not, the cheapest way around. But that's part of our support that we are paying for for that particular—to operate in that particular part of the world.

Mr. **Walgren**. Let me ask you about the social sciences and a concern that when you show increases in, and relatively larger increases, in the biological, behaviorial, and the social science directorate, that the emphasis is in the biological and particularly with the biotechnology initiatives; an area that the social sciences don't really participate in. And therefore, the personnel structure of the social sciences are left out and they are left out of the excitement of the research and the progress that's made in that area. And therefore, college students who would be planning careers will tend to avoid the social sciences, and pretty soon the pipeline of very bright researchers might get quite empty.

Can you tell us how you're addressing that concern?

Mr. **Bloch**. Well, let me give you a few facts. First of all, the increase this year in that particular area is about $1 million out of $30. That's not that far removed from the other increases in that particular area.

Let me just remind you that last year was a year where a significant increase was obtained for this particular area. In fact, it would have been higher if it hadn't been for Congress reducing our budget request. We had earmarked $5 million for it. We wound up with about $3 million. So we still, even after the cut from Congress, we still protected that particular area.

I also want to remind you that the low point of the behavioral sciences probably was around $21 million a few years ago. It's now, as I said, up to $31 million. So it's a fairly significant kind of an increase.

You should also know that the social sciences are participating in the computational science and engineering initiative because of their use of large data bases, access to supercomputers, and so forth. So they are part of the structure of the Foundation. They are participating in the other areas.

So, I think all told, in the last couple of years in particular, social sciences haven't done that badly. I know the history of it, it's not a very good history. On the other hand, the social sciences and behaviorial and social sciences, the content of the research that we are doing today has changed dramatically. And I think it has changed into the areas that are the right ones to consider. So I think we have done fairly well in the last few years, and I know the history is not quite what you would like to see.

Mr. **Walgren**. Well, I just want to do everything I can to keep the Science Foundation focused on the vitality element, because I think all agree that there is a tremendous contribution to be made in that area. In years past we felt that the contribution we were making to the national data bases was a substantial contribution to strengthening the social sciences inasmuch as they were very interested in having that data.

And now I understand in the reorganized social and economic science division of the behaviorial and biological sciences directorate that these data bases will continue to be supported.

Mr. **Bloch**. Yes.

Mr. **Walgren**. Where in the division are they supported? Are we still looking at that support money as our contribution to social sciences?

Mr. **Bloch**. Well, that's one contribution to social science. It's not the—that's not the total contribution to it. Dr. Moore, do you want to comment on that?

Dr. **Moore**. I don't remember the exact figures right now, but I think support for those—the three major data bases would be on the order of what, about a third of the SES budget. So about two-thirds of that budget is going to other kinds of research.

And I think a central thrust in that whole area has been in the direction of moving the social sciences in the direction of quantitative analysis. And therefore, the support of those data bases is an extremely important part of the program from an intellectual point of view.

Mr. **Walgren**. I'm sorry if I missed the answer, and I was trying to think of a couple of things at once. The level of those data bases' support is being maintained.

Dr. **Moore**. Yes.

Mr. **Walgren**. And the funds will come from what part of the organizational chart?

Dr. **Moore**. It's in the SES program.

Mr. **Walgren**. I see. As I understand it, the information we have does not break that down on that level, and we do want to know where that is and what that means with respect to the balance of that account.

Mr. **Bloch**. Dr. Kingsbury is the assistant director of BBS, and he can answer the question.

Dr. **Kingsbury**. All of the major data bases are supported in the division of social and economic sciences. That's the national election study, the panel study on income dynamics, and the GSS. And those are supported at the divisional level. That is, the moneys are aggregated by the division rather than putting them strictly back within a program.

And the reason for that is to maintain the balance between imperical research and the data base research. For example, if the political science program was solely responsible for the national election study, the program eventually would go bankrupt because of the high cost of the data base. In order to maintain a certain amount of empirical research in that program we try to bring those up to a higher part of the division. But they are done at the division level.

In addition to that, other smaller data bases are also being constantly examined, there's a few new ones that are started, and a few others that stop. Part of that program is in addition to the major data bases that we have in place and are maintaining, and are constantly reviewing, I might add. There's a move toward trying to more efficiently utilize these large aggregates of data that are collected by the government in a form that are unsuitable for social sciences research.

So, within the program of measurement methods and analysis, there's a constant effort to try to utilize and find better mechanisms of utilizing existing large data bases which were not established for social sciences.

Mr. **Walgren**. Well, we appreciate that and that certainly seems to make sense, but we'll follow it with real interest. Can you comment on the funding for ethics and values in science and technology, and the rationale for moving that program to the biological, behavioral, and social sciences directorate?

Mr. **Bloch**. Yes. We talked about that last year already, Mr. Chairman. I would like to remind you.

Mr. **Walgren**. I just don't want to let you forget, that's all.

Mr. **Bloch**. It's inscribed on my back.

Mr. **Walgren**. OK. Well, perhaps with that comment we could go on.

Mr. **Bloch**. I'll be glad to answer the question. As you know, we canceled out the program last year. We had some discussions. And the prime reason for it was because—personally, I felt that the program should really be more directed toward applications instead of philosophy subject matters.

We had some discussions here with your committee and with some of the Senate committees on it. At the end of the discussion we proposed that we move that particular program and the responsibility for it in Dr. Kingsbury's area so that it's close to some of the biotechnology kind of questions and some of the risk assessment areas which Dr. Kingsbury and his directorate are responsible for and also funding.

We have been asking the House Appropriations Committee to agree with us to spend $500,000 on that particular program this year with the understanding that we're moving it physically, that it will be aligned with some of the other areas and activities that are going on, and that over time I would hope that the program would take on a different kind of a complexion than what it had in the past. And that's where we are.

Mr. Walgren. OK. Is there any ability to encourage the participation of social sciences in the engineering research centers?

Mr. Bloch. Well, some of the social science activities, I'm pretty sure, are included in there obviously. Economics, economics plays a very important role in engineering research and in engineering design. Human factors, OK, is becoming a very important—has become a very important kind of subject matter.

So things—disciplines of this sort that are part of the behaviorial and social sciences, I think we will find their role in these engineering research centers. I'm very much convinced of that.

Mr. Walgren. Well, I know that we would be particularly interested in that because I, for one, am interested in following the development in that area and I know others are as well. It would be interesting, as those centers develop, if somebody could give us a view some time about the participation of the social sciences either through human factors or other kinds of areas, because we don't want to let something get forgotten that shouldn't be forgotten.

Mr. Bloch. Well, also the whole learning area is one of very great importance these days in artificial intelligence and other related subjects. So there are many areas where the two disciplines, major disciplines, essentially cross, and we'd be glad to provide that to you.

Mr. Walgren. Good. Turning to science and engineering education, I understand that you're carrying over, or that you had the carryover last year, so the amounts that you're allocating in that area demonstrate a real continued commitment, and, in fact, an increased chunk of sort of currently disposable dollars, I guess. So those--I can certainly appreciate the feeling that you're doing everything you can for science education in this particular year.

We do have a commitment that all—for this function in 1986 will be spent. Is that your previous thoughts?

Mr. Bloch. That's correct, yes.

Mr. Walgren. And you've indicated that you certainly don't expect any carryovers in that area.

Mr. Bloch. Definitely not.

Mr. Walgren. Can any projection be made for future years? The problem has got all of our attention. We're all concerned about unqualified teachers, and the assessments of the present quality is not encouraging. Many, of course, are highly qualified, but it is still an area, as I understand it, where people are still being pressed into the function of teaching in secondary schools, in particular, without that being their real area of interest and their real profession, or that area being their discipline.

Can you make any comments or give us any comments about what you see in the future in this area?

Mr. BLOCH. Well, let me make a general comment and then I'll address your question. We need to realize that the Foundation is spending roughly, as I said before, $89 million, or call it $100 million, probably in total in that particular area—a lot of it in the precollege area. And there are probably $100 billion being spent in this particular country on that precollege area. So we, at best, we are a small actor. I hope we are a very important actor inasmuch as we can concentrate on certain activities, and through those activities essentially help the problem, No. 1, and also put examples in place that other people can then take and augment on and imitate and duplicate, and so forth. That's our role.

Our role is primarily that of a catalyst. We can't possibly solve the total problem.

Mr. WALGREN. Right; could we ask whether there's a good evaluation of a current effort in this year so that we could appreciate, to the degree that we can, the value delivered per dollar at that point?

Mr. BLOCH. Well, that's part of the role of the management plan that we are putting in place and, that I mentioned, we are just starting to fund. It's a role of that essentially to find out how successful we are in those—in the programs that we are undertaking, what the effect of these programs is so that we can learn from it, No. 1, and also drop certain things that don't prove very——

Mr. WALGREN. I see. That's not just a study of the structure of the management, but actually the value of the program.

Mr. BLOCH. It's also the value received for the investment that we are making. We also internally, while that is going on, are always asking ourselves how many people are we essentially touching with this particular program, and what the results are, and how many are participating, and what happens to the information that we are transmitting.

We are trying to build a network, not just depending on the individual that we interface with. But they, in turn, can then be used as a resource to teach some of the other teachers and communicate some of what they learn to the other teachers. So we are trying to do that as much as possible. But at best we can only be a catalyst. We can't solve the total problem.

Mr. WALGREN. Would you expect the role of the catalyst to be an increasing one in terms of budget levels that you would recommend internally from the Foundation's perspective as opposed to what you might get through the administration's other priorities?

Mr. BLOCH. Well, I think we should be very careful that we don't get into the same situation we were in in the past, where we build up this particular area just to see it torn down a few years later and starting from scratch again. And that's why I think it's very important that the programs that we are putting in place are well considered programs, they are well executed, they are well evaluated, as you mentioned a minute ago, so that we know what we are doing.

I wouldn't want to see this particular area increased by leaps and bounds. I would like to see it given good increases in line with what they can do. But I think it's the program control that should drive the dollars.

Mr. WALGREN. OK, I understand. Dr. Moore, did you want to add something?

Dr. MOORE. I just wanted to add that besides the management study that has just been funded, contracted out, there is a program within the directorate to provide for studies and assessments of the programs that are in place. So there are two evaluation mechanisms in operation in that particular——

Mr. WALGREN. Do we receive those kinds of evaluations as they're produced? Does the Congress receive them or——

Dr. MOORE. Well, you certainly can receive them. I don't know that we have anything in place to——

Mr. BLOCH. I don't think that we have anything to show you today, but you're certainly welcome to them.

Mr. WALGREN. Well, when—this management study will bear fruition in what timeframe?

Dr. MOORE. Approximately 18 months.

Mr. WALGREN. Eighteen months? And the internal assessment should be coming along month by month.

Dr. MOORE. Well, they're on an irregular basis, on a project basis.

Mr. WALGREN. Yes; well, we would be interested in that, and in both your successes and your difficulties. I hope that our staff can keep in touch with you in a way that we would be able to appreciate the kind of feedback that you're getting.

Now, science engineering education, or science education in particular, is supported among several directorates, again with a relatively loose coordination at least structurally. It's my understanding that funds are spent in this area by the other directorates.

Can anything be said about the ability to view the overall and make the overall function as effectively as we can?

Mr. BLOCH. Yes; we can pull together in a cross-directorate way what funds we are spending for education in total. And we'll be glad to make that available to you.

Mr. WALGREN. I think we ought to see the total just as a submission and that would help us interact with your people on that subject. Turning to advance scientific computing, I want to particular say that we have, from the Pittsburgh area, watched with interest the development of the several National Science Foundation supercomputing centers and are very supportive of that.

Now the emphasis is changing in networking, is that right? And can you—I'd like to give you the opportunity to comment a little bit about where you see this program driving. How complete will the national research network be? How broad will these five centers now reach? And inasmuch as it's our understanding that various evaluations have always recommended spending more on supercomputing, and we have seen estimates in the hundred million, hundred billion-plus range, and we're in the 46 million dollar range as I understand it.

I'd like to give you an opportunity to lay out the new thrusts that you want to see happen in that area.

Mr. Bloch. Well, first of all let me say that the emphasis is not changing to networking. It's an area that we are going to address more and more, especially in 1986 and in 1987. We are obviously keeping our eyes on the computer centers per se because they are the foundation for it.

But the plans that we have are trying to capitalize on existing network structures. For instance, ARPANET. We have just finished a few months ago an agreement with DARPA, which is responsible for ARPANET, on the expansion of ARPANET so that we can tie in these supercomputer centers into the ARPANET.

The consortium networks are being established to connect 32 institutions—for instance, to San Diego—and about 20 institutions, 16 or 20 institutions, to the VonNeumann Center in Princeton. And the Pittsburgh center has a commitment now to network its capabilities maybe with something like 15 to 20 kind of consortia.

We probably will have in place by the end of this year a network that can link something like 100 or 120 universities. And that's pretty sizable. And we want to expand it. The backbone of the network is the 56,000 bit per second kind of a line which gets us away from the telephone line speed. It's still inadequate for the performance, but it's about the only thing that's really affordable, economically affordable right now. And we will have that backbone network, which interlinks all of these five centers that I talked about, completed in 1986.

And then, within those centers themselves, they in turn can link other institutions into the centers. And therefore, those centers—those institutions that are linked in an indirect way can also utilize that particular backbone network.

In the future we have the strategies to connect some of the other networks that are in existence, like CS-NET and BIT-NET, into the NSF structure, and with protocols that are being developed right now. We are also experimenting—and I want to underline it's an experiment—with the low cost small Earth station to see what we can do in terms of satellite transmission and how that would work out. Again, it's an ecomonic problem primarily, and that's why I said it's a pilot facility or an experiment.

So, over time I hope that we can connect all of the research universities and all—and not only the research universities, but all the universities that have any kind of an access requirement to supercomputers in that network. It's an ad hoc network that is springing up. Obviously we are trying to leverage what's in existence. We're trying to build on that one, but it will require that we are spending quite a bit of money and quite a bit of effort in this particular area.

It's a fast-moving field. What's in the forefront of technology today is no longer in the forefront of technology tomorrow. So it's very difficult of catching, you know, catching that moving train.

Mr. Walgren. Do we envision more centers, per se, ultimately?

Mr. Bloch. Well, ultimately I would hope that we have more centers, yes, because I think we need them. In 1987 we won't be able to afford it and do the other things that I talked about, the education aspect and the networking aspect.

Mr. Walgren. As you know, the consensus that gets put together in the Congress has a life span that's longer than 1 year or 2 years, so it's important to try to measure these needs even when we're not in a position to fill them.

Mr. Bloch. Right.

Mr. Walgren. And along that line, I'd be curious what NSF had asked OMB for in the supercomputing area, and then what finally made it through in the budget.

Mr. Bloch. I'm not absolutely sure right now. We asked obviously for more than we got. I think it was around $60 million. It was pretty close? Gee, we didn't aim high enough.

Mr. Walgren. OK.

Mr. Bloch. It's within a few million.

Mr. Walgren. Turning to the ocean drilling program now? We understand the House Appropriations Committee approved indemnification authority for this program. And why is that necessary? And how does that authority change the Government's responsibility?

Mr. Bloch. Well, let me comment first on the Ocean Drilling Program and then I'll talk about the Indemnification Program. We have now five—as you know, it's an international program. We have now five partners; namely Canada, Germany, France, Japan, and the United Kingdom. We probably will get a sixth partner in the foreseeable future; namely a consortium of smaller European countries that get together as one membership under the European Science Foundation coordination.

We also have invited, and I have written a letter, to the Soviet Union to invite them to participate. I have not received any answer. The letter went out in October. So we are looking forward to at least one more participant.

The program is doing very well. It's on target, it's performing the way we want it to perform. Costwise it's on target also.

Now let me get to the indemnification question. It's a standard and reasonable industry practice, first of all, that purchasers of services, like drilling services, either offshore or onshore bear the risk. The contractor is not able many times, and also not willing, to risk the company essentially for this particular service, because it's really the purchaser who determines where he should be drilling and where he should be using his investment. It's not up to the contractor itself. So the purchaser has a responsibility.

And we want to have that freedom because we want to determine where we want to drill, and not the company that operates the drill ship. So that's the point. It's a really low risk for the Government because the contractor is carrying about a $200 and a $500 million policy for riserless drilling and riser kind of drilling. And I believe very strongly, and the people that have looked at that very thoroughly believe that the risk of anything happening is very small.

They're not drilling in oil-rich areas, No. 1. We are monitoring what is being drilled while the drilling is going on. And if something should come up that could cause a danger, then the drilling is being stopped, the hole is capped, and you move on to another area. You abandon the hole. It's different from drilling for commercial purposes.

So I believe—so I believe that the Government doesn't run much of a risk by having that indemnification clause. And second, it's in line with what industry practices are, and we're using an industrial contractor for it.

Mr. **Walgren**. Does this question of indemnification come up in other areas that the NSF is active in?

Mr. **Bloch**. The NSF has been active in?

Mr. **Walgren**. Yes.

Mr. **Bloch**. I think it came up in the previous drilling program.

Mr. **Walgren**. But it's a principle that is confined to the ocean drilling thing at this point.

Mr. **Bloch**. Did it come up in the previous drilling program? Right, it would have come up then. But it's not coming up in any of the other areas that NSF is active in.

Mr. **Walgren**. OK. You touched on this—the invitation to the Soviet Union, and that raises the point of the international reach of NSF, and the Science Board's and the task force suggestions that we have a special assistant for international affairs.

Are we doing that? How do you see the international role of NSF at this point?

Mr. **Bloch**. Well, Dr. Moore is spending a lot of his time on exactly that particular subject, so why don't I let him answer.

Dr. **Moore**. I'm doing that because Erich asked me to be the interim Chief International Affairs Officer for the Foundation, in a sense following one of the recommendations of the Stever report in that respect. And has asked me to look at all of the international programs of the Foundation, to assess them, and to provide an evaluation and a plan that would address the concerns expressed or the wishes expressed in the Stever report, and also in the report of the Committee on International Sciences of the National Science Board.

To do that we have established a steering group that has been working for the last several months. We will have a report from that group by the end of May, according to the schedule we're now on. In the meanwhile, I would mention one other development in this respect.

As you probably know, OSTP has established a special committee of the FCCSET to deal with international science engineering and technology. And we are taking an active role in that committee and planning its operations and activities.

Mr. **Walgren**. I see. Let me then ask Dr. Schmitt, we've raised the level of contract approval of $6 million in the discretion of the director so that the Board could think about larger questions.

Is there close consultation on amounts committed below $6 million?

Dr. **Schmitt**. Well, as you know, the Board, following the new authorization bill, the Board did pass a resolution which raised the limits to a total commitment of more than $6 million, and a one year commitment of $1.5 million. Actually, that's only about in line with the inflation since the earlier numbers were in effect.

Now, that has permitted us to really step back and take a look at more strategic issues and more strategic questions. Our Committee on Programs and Plans, and the Education and Human Resources Committee are now undertaking reviews of various programs. For example, the Committee on Programs and Plans will review at least one program from each directorate each year. There will be 8 to 10 such thorough reviews each year. And those reviews are going to be chosen to reflect both big science and individual investigator center programs.

So, we—one of our reasons for wanting to do this was so that we could look at some of the programs that were smaller in size that normally did not come to the Board before.

We have in that committee completed recently reviews of long-term ecological research, for example, an interim report on the polar programs, and a review of the chemistry programs. We have ongoing reviews right now of the advanced scientific computing facilities. And, as I say, the polar programs are continuing.

We have scheduled reviews by the Committee on Programs and Plans as well as the education and human resources of the Math Programs, Social Sciences, Undergraduate Science and Engineering, Science Education, the Presidential Young Investigators Program, Physics, Materials Research. So we are, in fact, I think, addressing and using our time freed up by the new authorization to look seriously at important programs of NSF.

Mr. WALGREN. But we certainly want to encourage that.

Dr. SCHMITT. And I should—I'm sorry, Mr. Bloch reminded me, in addition to this increase in the authorization level, we did also publish an exception list, which I may or may have not seen, consisting of a set of programs that we have said even though they may fall over the limits, we've established the policy. We see no need to review those in coming years. These are generally programs where we have just recently reviewed, for example, a 5-year grant or a 3-year grant, and see no reason to have to review those again during the coming year.

That exception list is renewable each year. We will go over that list thoroughly each year. And if any of the conditions change in it, we will remove them from the exception list.

Mr. WALGREN. I see. Well, we want to encourage you in that. Let me ask you what, though, happens after you review an area, how does your review get communicated and integrated in the judgment of the Foundation itself?

Dr. SCHMITT. Well, we issue recommendations to the director. For example, they can be embodied in budget. For example, our math review we—which is ongoing now, we'll take a careful look at that report of the National Research Council, which we have received a report on from Ed David, who chaired that. And generally we will make recommendations to the director for him to consider in his budgeting process for those programs.

Mr. WALGREN. In addition to the individual reviews of finite areas, does the Board have a comprehensive input on the overall priorities that the Foundation——

Dr. SCHMITT. Yes, we do in the budget process. We participate very heavily in the budget process each year, and have a thorough discussion with the Director and his staff of their priorities that they are proposing. And the Board votes on the budget that the Director and his staff put together each year before it is submitted to OMB.

Mr. WALGREN. Good. Well, OK. Any other thoughts? Maryanne.

Ms. **Bach** [Republican technical consultant]. Dr. Bloch, one question that's come up within the committee is given the predicament with Gramm-Rudman-Hollings, and given the possibility that there may be a sequestration of some kind, and certainly Congress hopes that's not the case, but if there should be, you have a number of national facilities for which—which have been listed on the exception list with the Board.

You've taken up those contract negotiations with the consortia in recent times, so they are listed as not being on your schedule for the following year.

What is the critical point, and who determines within the Foundation what the critical point is in terms of any future cuts and whether you need to close down any facilities or make recommendations for alteration of the programs?

What is going to be the interaction between the AD's and Mr. Bloch and the Board and the consortia and the directors of those individual labs?

Mr. **Bloch**. Let me take it first and then you might want to add something to it. The interaction will be very intense, obviously, both with the directorates that are involved in it as well as with the Board. We are not going to close a facility without the Board knowing about it, and without the Board having an input to it. So, let me assure you of that if that was the question.

Obviously your question is somewhat hypothetical because I don't know when it's going—what's going to happen when or by how much, or anything like that. So I've got to answer it in a very general way. But closing facilities is not an easy kind of a thing to do, and it affects people, it affects programs, and so forth, and we are not going to take it lightly and the Board will be involved in it.

And obviously the directorates have to be involved in it because that's where it has to start, that's where the process starts. The identification of priorities, No. 1, in those areas, and the identification of needs and the identification of those areas or whatever it is, or centers that should be closed, it will come from the directorates. And I will be heavily involved in that, obviously, before it goes to the Board, and the Board will be heavily involved in it.

Dr. **Schmitt**. I would just like to assure you that every time Mr. Bloch has felt he was getting into trouble, he has called the Board in to work with him on the problem.

Mr. **Bloch**. Yes. I lean on the Board because I have to shoulder most of the responsibilities.

Ms. **Bach**. Yes. I think the question of the committee is going to be at what point does the consortium make a recommendation, versus does the—do the AD's and the program directors step in ahead of time.

Mr. **Bloch**. Well, it can also start from within the Foundation, OK? Maybe the consortium doesn't make a recommendation. Maybe we have to take the lead on it. The consortium is not going to put itself out of business very easily. You know that. It's against human nature. So, I'm afraid that would start within the Foundation.

Mr. **Walgren**. Well, on behalf of the subcommittee, thank you very much for your patience. We appreciate being able to touch these bases with you, and it gives us some way of pursuing the areas that we've touched on with you during the year. And we wish you the very best.

Mr. BLOCH. Thank you.

Dr. SCHMITT. Thank you.

Mr. WALGREN. Thanks.

[Whereupon, at 12:35 p.m., the subcommittee was adjourned.]

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1987 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

TUESDAY, FEBRUARY 25, 1986

House of Representatives,
Committee on Science and Technology,
Subcommittee on Science, Research and Technology,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:45 a.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Mr. Walgren. Let me welcome you to today's hearing. The subcommittee today holds its second hearing on the National Science Foundation's fiscal year 1987 authorization. Our first hearing, last Thursday, was a good session with the Science Foundation's top officials: Director Erich Bloch; his deputy, Dr. John Moore; and Dr. Roland Schmitt, the chairman of the National Science Board. They gave us a detailed but nonetheless an overview of the Foundation's proposed budget and raised some of their plans and initiatives that they are seeking to pursue.

The panel format this morning will be our way of hearing from individuals outside the Federal sector. We are pleased to have with us for the first panel representatives from scientific and professional organizations, including Dr. David Hamburg, chairman of the board of directors of the American Association for the Advancement of Science; Dr. Robert Rosenzweig, president of the Association of American Universities; and Dr. Robert Krauss, the executive director of the Federation of American Societies for Experimental Biology.

These witnesses will discuss the impact of the proposed NSF budget on their various areas of interest and the budgetary position of the Congress impacting on university research.

Operation of the major research centers in astronomy, atmospheric research, Earth sciences and ocean sciences comprise about 10 percent of the National Science Foundation's research budget.

We have today the members of the second panel, which will be presidents of the university consortia that manage these centers. Dr. Clifford Murino is the president of the University Corp. for Atmospheric Research, which manages the Foundation's National Center for Atmospheric Research at Boulder, CO; Dr. James Baker, the president of the Joint Oceanographic Institutions, Inc., which manages the Foundation's Ocean Drilling Program; Dr. Robert Hughes, the president of the Associated Universities, Inc., which operates the National Radio Astronomy Observatory; and Dr. John

Teem, the president of the Association of Universities for Research in Astronomy, Inc., which operates the National Optical Astronomy Observatories.

We want to welcome all of you and look forward to your views and perspectives. I ought to say at the outset that I apologize for starting a little late. I guess there is nothing we can do about that now, but I would like to encourage all the witnesses to consider the length of the hearing and the testimony of others as they present their own, and, therefore, I would like to ask people if they could summarize and underscore the points that they feel are most important to make orally in something like 10 minutes or thereabouts.

Written statements will be made part of the record, and, therefore, will be available to all those who will refer to the record as we develop it, and that will, therefore, have the details of your points fully developed.

I think it is clearly best in the oral presentations to try to outline or to direct our attention to those points that seem to be most important from your perspectives, and I am sure that that approach will further the interest that you are involved in in the best possible way.

So, with that, let me turn to my ranking minority member, Congressman Boehlert, from New York, for any thoughts that he might like to make.

Mr. **Boehlert**. Thank you, Mr. Chairman. I will be brief.

Last week, we heard NSF officials tell us what they would like to accomplish in the next fiscal year. Today's witnesses should be able to help us answer two key questions: What priority should be given to NSF funding as compared with that of other science and education agencies, and how well is NSF managing its large, national, contracted facilities?

The importance of these questions is obvious. This committee has to make some tough decisions in the coming weeks. Before we vote to increase the NSF budget, we have to be sure that the people who know the agency's programs best think an increase of 8.4 percent is warranted.

We also, of course, have to make some decisions about priorities within the agency—decisions with which the management consortia should be able to help us.

The decisions we make about NSF will have implications far beyond the confines of science—they will affect our economic future. Scientists and Federal officials have to work together to develop a productive national science policy.

I look forward to hearing this morning's advice.

Mr. **Walgren**. Thank you, Mr. Boehlert.

Congressman Ritter, any opening remarks?

Mr. **Ritter**. Thank you, Mr. Chairman.

I would like to welcome our witnesses for today. I would just like to say that I feel that investments in the National Science Foundation are amongst the best investments that our Federal Government makes, and I do want to see, even in an era of Gramm-Rudman, that we take care of our future and that we don't consume our seed corn, and that we can continue to make even some modest investments in the economic and technological competitiveness of the future of the United States.

So, I am not sure what is going to happen when this budget increase finally comes to the floor, but at least I think we are starting in this committee with the right idea that cutting the Federal budget should not mean cutting everything equally in a way that does not assign priorities.

I would like to put in a good word for NSF's attempt to link the academic institutions more closely with American industry on behalf of the idea of industrial competitiveness and international competitiveness, and I think the engineering research centers, the engineering research groups, are designed to increase the university-academia interaction. I think it is certainly in the best interests of the Nation.

I would like to put in a good word, too, for broadening the technical base by the innovative EPSCOR Program, the experimental program to stimulate competitive research, which helps build science and engineering capability in States that have not received large numbers of NSF awards in the past.

So, Mr. Chairman, with that, I look forward to some of the testimony. I must say that I do have another hearing, and that is in the Energy and Commerce Committee, and it is a hearing that is very much related to what we are doing here. It is entitled: "Hearings on H.R. 3813, To Increase Productivity and the International Competitiveness of U.S. Industry." So, it is a subject that is probably dear to the hearts of a lot of the people in this room.

Thank you, Mr. Chairman.

Mr. Walgren. Thank you, Mr. Ritter.

Well, with that, let's turn to the first panel and call up Dr. Hamburg, Dr. Rosenzweig, and Dr. Krauss.

There has been a request that we allow some pictures to be taken, and, without objection, that will be the order, and you are certainly welcome to——

Mr. Ritter. I object, Mr. Chairman, unless we are in them. [Laughter.]

Mr. Walgren. I understand that feeling, but I am sure, given the purposes for the picture, you have our encouragement as well.

OK, let's start in the order that we called you and go through the several witnesses and then come back for some discussion.

Dr. Hamburg, welcome to the committee.

STATEMENTS OF DR. DAVID A. HAMBURG, CHAIRMAN, BOARD OF DIRECTORS, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE; DR. ROBERT M. ROSENZWEIG, PRESIDENT, ASSOCIATION OF AMERICAN UNIVERSITIES; AND DR. ROBERT W. KRAUSS, EXECUTIVE DIRECTOR, FEDERATION OF AMERICAN SOCIETIES FOR EXPERIMENTAL BIOLOGY

Dr. Hamburg. Thank you very much, Mr. Chairman. I am delighted to be back here again. I do appreciate the privilege. I do think, in general, that there is a wonderful kind of permeable membrane between the scientific community and the policy community in this country that may well be distinctive, and we do not take that for granted. We do appreciate very much what that means, and we hope it is mutually beneficial for the two communities.

The central thrust of what I want to say is very much in the spirit of what, in fact, has already been said. Mr. Ritter's investment emphasis is precisely the right one in our view. The AAAS, as you know, is the broad-rimmed organization for American science and engineering. It really tries to concern itself with the whole of science and technology—a very difficult thing to do; but given the large size of the organization and the wide range of the affiliates' societies, and so on, it is possible, to a certain extent to keep broadly informed about major trends and currents in the scientific and technical community.

This is only a preliminary analysis, the suggestions we make today. A more definitive coverage will be in our R&D colloquium on March 26 and 27, which, as you know, has become one of the principal institutionalized features of American science policy, and I hope that you can get to that, or some part of it, at any rate, on March 26 and 27.

Now, it is clear that people in political life, as well as scientists and engineers share a tremendous responsibility for nurturing a favorable environment for science and technology in the United States, not only because the intrinsic importance and fascination of those fields, but what it means for the future of the economy and society altogether.

I included in my testimony a brief summary of an event which I happened to attend and participate in about a decade ago, which left a lasting impression. At the Nobel ceremonies in 1976, just a decade ago, the Americans that year won all of the Nobel prizes, and the chairman of the Nobel Foundation, a great biochemist, Sune Bergstrom, of Sweden, in his opening address, said: "What is this; is this some kind of a gift the Nobel committees are making to American science?" Hardly, and he went on to explain the very careful procedures they use and all that.

But more than that, he said the really interesting question is not that the Americans happened to have won them all this year, but how it is that Americans have won so many for so long and, in general, how it is that American science and technology has been so preeminent. And he stated what in his view were some of the essential conditions, or at least the strong desiderata for the flourishing of science and technology as manifested in the United States more so than in anywhere else in the world, in his view.

And let me quickly read those, because I think they really do matter a great deal and give a kind of framework for thinking about what it is we are trying to preserve and cherish when we address these questions.

First, the recognition that basic science can have powerful practical consequences.

Second, generous immigration policies in this country which permitted many outstanding scientists from Europe and elsewhere to come to the United States. It has sometimes been said that quite inadvertently Hitler was America's best friend. Mao was a pretty good friend of American science as well. But the immigration policies permitted people to come from other countries where they were in unpleasant circumstances and quickly move into productive careers here.

The third point is recognition of the importance of science and technology for economic progress.

Another is the intellectual stimulation and the fostering of innovation made possible by the extraordinary political freedom and economic freedom and open communication that we have in this country.

Another is the strong national commitment to the support of basic science through institutions such as the NSF and the NIH.

Another important point is the democratic atmosphere of American universities and their laboratories, in contrast with the hierarchal, authoritarian structures prevailing in many other countries, including some democratic countries.

And, finally, the special attention that we have given in this country to the fostering of research by talented and dedicated young people, opening up pathways and offering hope early for talented young people across the board, regardless of social background.

Well, I am sure others could be added, but Bergstrom's set is a very important set of conditions for the flourishing of American science and technology and its effective use in the society that we do need to keep in mind, especially at a time of budgetary stringencies.

That does involve a concept of R&D as an investment, as Mr. Ritter just emphasized, that is coming to be much more recognized in the past, say, 5 or 7 years by American industry than it was before.

It is important to bear in mind not just high-technology industry, but we now see increased commitment to applied research and development over a very wide range of industrial firms, and it may well be that the principal hope of the so-called smokestack industries will be through the strengthening of R&D, which a decade or two ago they did not typically see as a high priority consideration.

Now, throughout our history as a people, our economic success has been very much related to science and technology, though in different forms at different times of our history. We had, for a long time, a very openminded pragmatic orientation to using technology in relation to our natural resources for the general well-being.

A lot of that is a commonsense approach of imaginative craftsmanship, as exemplified by our great inventors, but even by the Civil War time, President Lincoln recognized that we would have to orient more to fundamental science as a way of generating technological innovation and utilizing that, whether it be in the military, as in the case of the Civil War, or for the economy much more broadly.

We have, in effect, come to have a broad definition of what constitutes national security, not just military, for the strength of the economy, or the strength of the society, altogether, in which we have given science and technology virtually an unparalleled place.

Science is not a separate activity, very arcane and remote from the lives of people. To the contrary, it is really bound up with everything that we do central to modern living, not only in a material sense, but actually in the sense of social justice as well.

So, when we are talking about the vigor of scientific enterprise, it really is the future of the society. Research and education are really the cardinal investments for the future of the society.

Overall, the R&D budget has been going up, and it looks good. So far, the Gramm-Rudman-Hollings' effects have been mixed and limited, although in the outyears, as you know, they could very well be formidable.

The major trend in the R&D surge of the past 5 to 7 years has been on the defense side. The fiscal year 1987 request shows that 73.4 percent of the total R&D is in military R&D. It is a staggering figure; it is an enormous commitment there. And we have to keep in mind the civilian side, which bears most directly upon the domestic economy and international competitiveness. There are, to be sure, spinoffs of military R&D.

The direct focus on the domestic economy is a crucial consideration, and underlying it all, both the domestic economy and the military strength, is the contribution of basic research, where we do have an unparalleled commitment, but many other countries are catching up. They are not stupid; they understand what it takes to go the route we have gone, and most of them, of course, have much less of a military load to carry and, therefore, can focus more clearly on basic research and on the applications and domestic economy.

So, we have to keep in mind a balanced development of R&D as we look at the overall picture. Certainly the NSF has generally done well. It is one of the few civilian agencies that received a healthy increase in the current budget—8.4 percent. The emphasis within that placed by the Foundation seemed to us to be generally appropriate—physical sciences, engineering, biotechnology, and computation. Space was also singled out, which is logical, although, obviously, there are concerns at the present time in sorting out the meaning of the shuttle disaster. One hopes that will be transitory.

There is a leveling off of resources related to agriculture, and we question the wisdom of that, and there is a leveling off in energy and environmental research and development. Elsewhere, reductions are the order of the day in Transportation, Interior, Commerce, and the NIH, although, of course, one assumes—no doubt the administration assumes that the last word has not been heard on that. The Alcohol, Drug Abuse and Mental Health Administration is also not favored despite the fact that the mentally ill are now on the streets everywhere, and there is very deep concern about alcohol and other drugs. Nevertheless, that agency also is not favored.

These are not entirely budgetary considerations related to Gramm-Rudman, although all of these trends reflect the administration's priorities over the past 5 years.

The longer term effect of Gramm-Rudman, if pursued in the way that they have been talked about before, could be very serious, indeed—could even be disastrous. I personally am extremely skeptical that the Nation's leadership will permit that disastrous course to go forward, but, if one makes a kind of literal projection of those figures for science and technology in 5 years' time, to understate the matter, we would be in very deep trouble.

The particularly distinctive responsibility of the Federal Government is in basic research. In the AAAS effort to keep in touch with corporate research and, of course, with the foundation world, which is my own personal responsibility, it is clear that both the for profit and nonprofit private sector has only a modest contribution to make to basic research.

Applied research is a different story. Development, a different story. But the distinctively Federal contribution, and also the States, although they contribute a little, are not likely in the foreseeable future to pick up very much slack in basic research. So that matter of profound significance is the platform on which we build all the rest of our technical achievement and the application of that achievement in our economy and military, and across the board.

Now, the effects of Gramm-Rudman on our education will be severe, and that is a matter that Dr. Rosenzweig can speak to better than I, we have in the AAAS, like the NSF, have been focusing on precollegiate education, and we believe that the NSF's emphasis on precollegiate has been quite appropriate. You know the litany of problems delineated in the reports of recent years about precollegiate education. That is a fundamental foundation of science education that has got to be addressed in new ways: first, with respect to pipeline for careers in science-based professions, and, second, for an informed citizenry in a democratic society to be literate in science.

It is a tremendous challenge. We have got to find ways to link the science-rich sectors; namely, the universities and the corporate labs and the national labs, with the science-poor sectors in the elementary and secondary schools. We may be at a historic moment for the transformation of education in the country, but it will take a Federal commitment in science, even though, of course, the main education responsibility is State and local, but the science enterprise is so very complicated, so massive, and sometimes so expensive that there has got to be a national leadership function, and NSF is in the logical position for that.

We do, as my testimony indicates, regret the very slow pace of the NSF in moving. The Science Board has provided us with a superb report a few years ago; the science board continues, and leadership people in the NSF continue to be concerned with the problem, and yet the pace is too slow, the numbers are too small.

We are at a point now where the NSF should move not only from precollegiate education to a focus on the undergraduate years as well. A crucial thing for the economy of the future, as all of our studies show, is a skilled, adaptable workforce, probably a more adaptable workforce than we have ever had before, given the fact that so much of internationally economic competition will hinge on being able to move rapidly and take advantage of new technological developments as they come along.

So, that science education is a fundamental underpinning for the economy of the future, and there has got to be a national leadership commitment to that, working closely with the States and stimulating their activity, to be sure.

The Science Foundation is showing quite a lot of imagination in education. For example, in television, which we could pursue if you want to later on, the ingredients are there. Dr. Shakhashiri, in my judgment, is doing a good job as heading the science and education directorate, but they need a lot of support and encouragement from the Congress to make things really happen.

The international side is being strengthened, is getting attention from the Science Foundation in appropriate ways. The international geosphere-biosphere enterprise is a very good one picked up from a report of the National Academy of Sciences and carried forward.

Another one that in my judgment is very important is the utilization of the life sciences for development in Africa. There is a tremendous opportunity in the face of the African crisis to pursue that.

A word about international scientific cooperation: there is a lot of serendipity in that. Dr. Comrow, Julius Comrow, a great biologist in California, used to say that serendipity is like looking for a needle in a haystack and finding the farmer's daughter. And, I think, there is something to that in international science cooperation. That is to say, with a tendency to generate a lot of new knowledge in mutual benefit between our country and the countries we work with, and also to strengthen their international relations.

There is a unique character to scientific cooperation, and you might speak of a kind of science diplomacy. So that there is really serendipity in international scientific cooperation. A lot more could be said about that.

We at AAAS are still very worried about the infrastructure of American science. Your committee has addressed that. It looks like there may be a little progress on equipment facilities in the current NSF budget, but not nearly enough. It is very worrisome, indeed.

We express concern in the testimony about behavioral and social sciences. We point at three areas of enormous importance. One is conflict resolution. Another is the economy in relation to technology, and another is health and behavior, which might be done cooperatively with the NIH and NMHA.

Those are three very critical areas in which behavioral and social sciences require more attention than they are presently getting in the NSF.

So, overall we think it is a good NSF budget, considering the circumstances. We are mainly talking about some matters of emphasis within it. We think the NSF has good leadership, that the Science Board is doing a good job, but we are mostly concerned that we not lose sight of the significance of science policy decisions for the future in the time of budgetary stringency.

Finally, I would urge, Mr. Chairman, that we think about additional mechanisms of ongoing science policy analysis, both within the Government and beyond. I would say, for example, the OTA is doing a superb job. As a creature of the Congress, you should feel very proud of what has been done.

There are some very good things coming out of the National Academy of Sciences and elsewhere. We need to think about governmental and nongovernmental sectors and ways in which institutionalized mechanisms would get us an ongoing, broad stream of good policy analysis, on what can science and technology do for the society in the future. We can discuss that more later, if you wish.

In any event, I appreciate the privilege of being here and the work of this committee, which I think is providing great national leadership in this field.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Hamburg follows:]

PREPARED STATEMENT OF DR. DAVID A. HAMBURG

Mr. Chairman and Members of the Subcommittee:

INTRODUCTION

On behalf of the AAAS, I would like to thank you for the opportunity of appearing before you once again. It is an opportunity that is all too easily taken for granted in this country; foreign colleagues often marvel at the openness of such forums as this and at the access enjoyed by U.S. scientists and engineers to those of you in the political world to express our views.

Although I am President of the Carnegie Corporation of New York, today I am here in my capacity as Chairman of the Board of Directors of the AAAS. Briefly, we are an umbrella-like organization whose members span virtually all fields of science and engineering; affiliated with us are some 285 other scientific, engineering, technical and professional organizations with a total membership in the range of five million.

Within the past decade or so, we have become more and more involved in matters of national science and technology policy and the public understanding of science and technology through our publications, various special conferences, hearings such as this, and our annual meeting. This growing interest in national policy matters is, of course, indicated in the depth of our support for this Committee's work and that of your Science Policy Task Force. Also, we have recently revised the format of our flagship publication, Science, to reflect a greater emphasis on science policy areas.

ORGANIZATION OF STATEMENT

Today, I would like to cover several major topics briefly based on our preliminary analysis of the President's FY 1987 Budget as submitted to the Congress. In the context of these major topics I will comment on specific aspects of the FY 1987 National Science Foundation Budget Request and respond, in part, to several issues which you asked that I address. I intend to talk about the following topics:

- Policy Environment for Science and Technology
- Overview of R&D: Federal and National -- Including the Arrival of Gramm-Rudman-Hollings
- International Science and Technology
- Infrastructure Issues: Facilities, Equipment and Instrumentation
- Management of Science and Technology

In concluding, I will offer several suggestions and recommendations for the Subcommittee's consideraton.

POLICY ENVIRONMENT FOR SCIENCE AND TECHNOLOGY

Politicians, Scientists and Engineers Share a Tremendous Responsibility for Nurturing a Favorable Environment for Science and Technology in the United States

In 1976, Americans made a clean sweep of the Nobel prizes in all fields, an unprecedented event. Was this some special birthday gift of the various Nobel committees to celebrate our bicentennial? Hardly! At the ceremony of Nobel prize presentations, Sune Bergstrom, a great biochemist who is Chairman of the Board of the Nobel Foundation, noted that Americans had won about half of the prizes during the preceding 25 years. In his remarkable opening address, he went on to point out some of the reasons for the preeminence of American scientists:

- The recognition that basic science can have powerful practical consequences
- Generous immigration policies which permitted many outstanding scientists from Europe and elsewhere to come to the United States
- Recognition of the importance of science and technology for economic progress
- The intellectual stimulation and fostering of innovation made possible by political freedom and open communication
- The strong national commitment to support of basic science through institutions such as the National Science Foundation and the National Institutes of Health
- The democratic atmosphere of American universities and their laboratories -- in contrast with the hierarchial, authoritarian structures prevailing in many other countries
- Special attention to the fostering of research by talented and dedicated young people

These comments by an astute observer of the world scene offer a magnificent array of beacons to help guide us through a period of budgetary storms. The emergencies of the moment may very well create pressures which could lead to us losing sight of important long-term goals.

Stating this another way, I would offer the following basic point: We must consider research and development as an investment in the future -- near-term and long-run. An expenditure for research and development is not just another expenditure, equivalent to, say, the purchase of office supplies. An expanding array of economic evidence supports the investment character of R&D in providing the basis for economic growth and improved human well-being.

Such a concept is increasingly acknowledged by our own private sector in this country and by other countries around the world. Indeed, it seems to me there is a strong political consensus here, held by individuals from all parts of the political spectrum, about the validity of R&D as an investment. While I acknowledge the real problems facing you

— and all of us — in dealing with deficit reduction, I contend that a sustained and robust national effort in research and development is fundamental to a strategy of economic and social growth as well as to improving the quality of life.

Some Brief Reflections on National Science and Technology Policy and Contributions of Science and Technology

American science and technology, as suggested by Bergstrom, have earned great respect throughout the world. In fields such as health, agriculture, space, communications, and computers, the world's respect for American science-and-engineering based achievement borders on awe.

Despite past achievements, perhaps the question might be raised, "In a 'bottom-line' sense, during a time of economic stringency such as the present, what difference would it make if we cut back for a time on our national commitment to science and technology to save money and reduce the responsibility of the Federal Government?" I would respond by saying, "While there are some things we could do which might be more foolish, there are not many." Why is this so?

Through most of our history as a people, our economic success was in substantial part predicated on an open-minded, pragmatic orientation to technological utilization of natural resources for the general well-being. Much of this was based on a common sense approach to imaginative craftmanship, as exemplified by many of our great inventors. However, over time, increasingly the new technologies central to economic progress and national defense — national security in a broad sense — came to depend upon advances in fundamental science as we invested in the future during the past half century.

Science and science-based technologies have become a pervasive part of human experience in the 20th century and the key to present and future well-being. Science is not a separate activity, remote from the lives of people -- however arcane it may seem to be. Science provides the structural foundations for most of the features of modern living and much of its promise for the future, not only in a material sense but also in relation to social justice.

If we are seriously concerned with economic growth, productivity, innovation and equitable distribution of the resulting benefits, as we should be, then we must also be seriously concerned with the vigor of our scientific enterprise. From this enterprise comes an increasing array of opportunities in every facet of human experience. Our food supply, our health, our global environment, our security, and our ability to make a living, to improve the quality of life and diminish human suffering -- all depend increasingly on science-based activities.

AN OVERVIEW OF FEDERAL AND NATIONAL RESEARCH AND DEVELOPMENT LEVELS

In this section I will discuss briefly several important features and possible trends involving national and Federal R&D, with special emphasis on the arrival of Gramm-Rudman-Hollings. Also, I will comment on the overall character of the NSF Budget Request for FY 1987.

The National Total for Research and Development in 1985 Reached Nearly $109 Billion -- Exceeding Over $100 Billion for the First Time

It is estimated that the total amount invested in research and development in the United States in 1985 will be in the range of $108.8 billion. The Federal total comes in at about $51.7 billion (or 47 percent), while the non-Federal component is estimated at $57.1 billion (or 53 percent). As Appendix 1 shows, the ratio has been essentially constant since 1980.

Appendix 1 also shows that total national R&D for 1986 is estimated to in the vicinity of $118.6 billion. Another important point is that after a long plateau of little real growth since the the mid-1960's, substantial growth began in the late 1970's (as shown in the constant dollar column).

It is also clear from an examination of the Appendix and other supporting data that the private sector is making significant investment in research and development as part of its various competitive strategies. The major focus is on applied and development activities in contrast to basic research.

The Arrival of Gramm-Rudman-Hollings Has So Far Had Mixed Effects on the Aggregate Levels of Federal R&D: A Reduction in FY 86 Was Made But the President Has Submitted the FY 87 Budget with Substantial Increases

While the overall Federal budget clearly shows the influence of G-R-H, and the FY 86 R&D total ended up at about $2.54 billion lower than the appropriated amounts, the overall FY 87 research and development level seems to be remarkably healthy. There are, however, various "symptoms" which seem to call for closer examination. For example, I would like to review with you the little table below which shows a comparison of aggregate numbers for Federal research and development, beginning with FY 1984. (The figures are for appropriations, i.e.,budget authority).

Total Federal Research and Development
(in billions of dollars)

	FY 84 Approp.	FY 85 Approp.	FY 86 Approp.	FY 86 G-R-H Impact	FY 87 Request
Total Fed R&D	$46.0	$51.7	$57.5	$54.7	$63.2
(Basic Research)	($7.1)	($7.8)	($8.3)	($8.0)	($8.6)
Basic Res. Percent	15.4%	15.1%	14.5%	14.7%	13.6%

Total Federal R&D Divided Between Defense and Non-defense

National Defense	$30.5	$34.7	$39.6	$37.6	$46.4
Non-defense	15.5	17.0	17.9	17.1	16.8
Defense Percent of Total R&D	66.3%	72.0%	68.9%	68.8%	73.4%

A quick look at these numbers shows that the total amount for Federal R&D has been increasing at a healthy clip. However, the numbers also vividly underscore NSF Director Bloch's statement to you last week that the already small share of dollars allocated to basic research is steadily dropping, even though NSF's budget fared well in a difficult budget period. I draw this latter trend to your attention in relation to my earlier comments about how important it is, very frankly, that the basic research programs of the Federal Government be protected in the coming budgetary battles. And the National Science Foundation's programs are squarely in the middle of the strongest candidates for such protection and nurturing. Any cutbacks in the basic research area by the Federal Government will not be picked up by the private sector — as we have testified many times before, based on extensive review of the types of R&D that industry does support.

A more detailed look at the entire budget -- although I will not review specific numbers today -- shows that its dominant feature is the overwhelming emphasis on national security research and development. Since 1980, this element has risen from about 50 percent of Federal R&D to over 73 percent in the FY 1987 budget request, and may well be on a rising trend. Other important themes in the overall budget appear to be as follows:

o Overall, the National Science Foundation was one of the few civilian agencies which received a healthy increase, 8.4 percent. The increases were largely in the physical sciences, engineering, biotechnology, and advanced computational capabilities — much of which was couched in terms of improving our industrial competitiveness. Space was another area singled out for increases -- although the shuttle disaster has raised considerable uncertainty about NASA's ultimate budget configuration.

o There is a leveling off of resources allocated to agricultural, energy and environmental research and development — as well for the Agency for International Development, the Veterans Administration and various other smaller agencies.

o Reductions are the order of the day for the Departments of Transportation, Interior, and Commerce, and the National Institutes of Health, although the last word may not yet be in place on these cuts.

These trends or themes do not seem to be results of G-R-H influences; rather they reflect the continuation of Administration policies in place for the past five years. Some of the reductions may well support deficit reduction objectives, but it would not appear as though this was the primary motivation, this year.

Future Effects of G-R-H Deficit Reduction Pressures Are Likely to Be Significant for R&D

However, as we attempt to peer ahead -- along with you -- it seems reasonable to forecast that the deficit reduction trend -- with or without G-R-H in whatever form it emerges from the Supreme Court review — is likely to remain a potent political force. Among the resulting effects it is quite possible that further pressures will be placed on so-called discretionary areas such as civilian R&D. Just as likely, we would guess that national defense R&D will be subject to the same kind of pressures.

In short, in the outyears of 1988-1991 it is quite conceivable that we might experience a drastic paring down of our national R&D capabilities -- including levels of research, production of scientists and engineers, and modernization of our research facilities, equipment and instrumentation.

Numerous concerns arise from this scenario; included is the basic problem of how we can preserve crucial elements of our scientific and technological enterprise and avoid foregoing or delaying follow-through on important opportunities. Finally, as I discussed earlier, there is the vital task of maintaining and investing in -- for the long pull -- a healthy basic research establishment, even if it becomes necessary to cut back on other parts of research and development.

While I am sure you will be presented with many examples of deficit reduction impacts, I think it is important to identify a problem which otherwise might be lost in the "noise level." First, I acknowledge that this is not your legislative concern; however, changes being discussed in postal rate policies could lead to substantial cost increases for distribution of scientific and technical journals -- the lifeblood of scientific communication. It is feared that such changes, if they come to pass, could have a chilling effect on many precariously financed journals, particularly in smaller or emerging fields.

Effects of G-R-H on Higher Education Will be Severe: Since Science, Math and Engineering Education are Integral Parts of Our Scientific and Technological Enterprise in the U.S., There Are Reasons to be Concerned

Although Dr. Rosenzweig will address education extensively in his testimony, we feel strongly about putting AAAS views on record. The FY 1987 budget for higher education, at $6.7 billion is 23 percent below the FY 1986 amount of $8.7 billion. And while the various programs deal with a broad variety of purposes, science, math and engineering education will be among the fields hit hard by the reductions. I will come back later to several specific comments on NSF's program and its education plans.

We have been coming before you regularly with our concerns about science, math and engineering education. Despite progress on a number of fronts, the looming impacts of G-R-H are reasons for serious alarm. The litany of problems has been well-documented in report after report and study after study, in recent years.

- There is very little science instruction in elementary schools.
- At the secondary levels too many students are unchallenged; there is a grave and worsening shortage of well qualified science and mathematics teachers; the curriculum lacks coherence and needs overhauling; and computer literacy is a major concern.
- At the present time, undergraduate science and math education receives almost no support.
- There is a low level of research effort on teaching and learning; resources are limited for the development of classroom materials; teacher training in mathematics and science throughout the precollege level is woefully inadequate.

During the past few years the nation has experienced a rediscovery of education, especially in the linkage between science and technology education and the economy. Much is happening at state and local levels under the influence of forward-looking governors and local officials -- but it would be a grave mistake to use such actions as the basis for the Federal Government to step aside from its own special responsibilities. Too much is at stake.

We may be at an historic moment in education with a challenge and opportunity comparable to the period of the Civil War when the land-grant colleges were established. Historically, education support has always been tied to other objectives, such as national security (Sputnik) or social justice (Great Society). Now, the emerging tie is to the scientific and technological needs of the new economy. With this emergence comes the urgent need to raise the status of education as a profession.

In thinking about the basic education issues, I think these are among the more important questions:

- How can we give all our children, regardless of social background, a good opportunity to participate in the modern technical world?
- What constitutes a decent minimum of literacy in science and technology that should be a part of everyone's educational heritage?

o Given the rapidity of socio-technical change, how can we make lifelong learning a reality so that people can adjust their knowledge and skill to technological change?

o Since educational institutions will more than ever be preparing people for unpredictable circumstances, how can they prepare for change itself?

o How can we broaden the spectrum of the sciences to include the full range of life sciences and behavioral sciences so that modern education will become increasingly informative with respect to human experience?

o How can the educational system foster a scientific attitude useful both in problem solving throughout society and in relating scientific principles to the major issues on which an informed citizenry must decide?

o How can we achieve an informed world-wide perspective in an era of profound global interdependence?

Such questions and the need to undertake systematic inquiry into them are founded in our strong belief that a fundamental transformation of our society and our economy is occurring as a result of the pervasive influences of science and technology. We believe there is the need for widespread and deep educational improvement to cope with accelerating change and that the current momentum — particularly in the states -- suggests a readiness for action.

This set of problems is far too complex to be dealt with using simplistic nostrums such as education is a local problem in our system of government." Of course, local control of education is at the core of our system; no serious-minded person even questions this premise. And, yes, far larger proportions of the total cost of education are borne at state and local levels but Federal money, experimental programs, and research activities provide highly leveraged capabilities that are difficult or inefficient to replicate at state levels. The massive, complex effort required in science education calls for national attention, stimulation, and leadership.

The challenge is to develop and carry out an effective mix of Federal, state and local educational activities to cope with the transformation I described a moment ago. I'm reminded of an old anecdote of H.L. Mencken's; he said: "For every complex problem, there is always a simple answer -- and it is always wrong." We need to work at meeting the real challenge.

NSF Budget Request in Science and Engineering Education is Something of a Disappointment: There is Too Little Progress, Too Slowly

Given the overall favorable treatment for the NSF budget, and the knowledge that Director Bloch, as well as the National Science Board, are serious in their intentions to improve the NSF's Science and Engineering Education program, we are reluctant to come down too hard in appraising the education budget and what lies behind it.

Nevertheless, we have concluded that, taking into account the importance of the overall national educational challenge discussed above, it is necessary to observe that there has been too little progress, too slowly accomplished. It is little short of astonishing to realize that a study to prepare a long-range plan, authorized and directed by the Congress in 1984 is just now getting underway with a target completion date of eighteen months from now.

Surely, it is not a matter of a shortage of reports and studies; I have already mentioned the plethora of such activities, including the excellent work of the National Science Board itself. We do hope the Subcommittee will exercise its oversight role in following the new study closely. In the meantime, we would like to offer several suggestions for the evolution of a national education program, largely under the auspices of the NSF:

o There should be a balanced program of support for science, mathematics and enginering education. Our system requires strengthening from the bottom to the top, i.e. from the precollege level, through undergraduate to graduate to post-doctoral levels. The specific needs at each of the levels has been thoroughly documented.

o Support should be balanced with regard to the functional activities undertaken -- research on teaching and learning; development of supporting materials; use of informal, out of school, approaches based in a variety of places such as museums; and training of teachers who are qualified to provide sound instruction throughout the precollege level.

o A strategic plan must be developed which is based on a reasonable degree of stability and growth commensurate with the magnitude of the problems previously described. The kinds of funds required have already been partially identified in the Board's own Commission Report on Precollege Education in Mathematics, Science and Technology.

o Finally, it seems logical that the National Science Foundation should provide the management focus on a national program of the kind we are discussing.

INTERNATIONAL SCIENCE AND TECHNOLOGY

Investment in R&D is Growing Among Our International Partners and Competitors

In earlier appearances, I and other AAAS witnesses have repeatedly focused on the international dimension of science and technology, both in terms of the connection to international economic competitiveness and to international cooperation, particularly in science matters.

As a brief update, Appendices 2 and 3 to my statement show the allocation of national resources to investments in research and development by a number of key nations: France, West Germany, Japan, the United Kingdom and the USSR. As a summary point, each of the nations -- except the United Kingdom -- continues to allocate an increasing percentage of its Gross National Product to research and development -- particularly in civilian-related areas.

Since I have in earlier appearances developed this line of thinking, I will only observe today that nothing has changed: the intensity of the international economic competitive environment is directly related to national investment in science and technology. A salient point is that our own national investment in civilian R&D has essentially leveled off while the Japanese ratio continues to increase (Appendix 3).

The AAAS Applauds and Strongly Supports Current Studies by the National Science Board and the Foundation Itself in Exploring Ways the NSF Might Serve the National Interest Through its Activities in International Science and Engineering

In supporting the Science Board's Committee on International Science, the AAAS endorses enthusiastically a recommendation of the Committee that the NSF assume a leadership role in planning and implementing one or more major global initiatives, in which other U.S. and foreign organizations could participate. For example, through our Consortium of Affiliates for International Programs we have been consulting widely with others in the scientific and engineering community to develop a list of five to ten candidate global initiative programs. From such a list it is hoped that a suitable activity or activities might be mounted.

A potential candidate has been identified in a special National Academy of Sciences Report as an "International Geosphere-Biosphere Program (IGBP)" which might be conducted under the auspices of the International Council of Scientific Unions (ICSU). While it would seem appropriate for the NSF to have a leading role, an IGBP should be truly international, for the concerns are those of the entire planet. Considerations of access alone would require the participation of scientists and technicians from both advanced and developing countries representing all parts of the world. Proposed study areas would include:

- The recovery of the past history of environmental change
- Changes in the current physical environment
- Global changes in the biosphere
- Global biogeochemical cycles
- The global hydrologic cycle

It is encouraging that the NSF budget includes increased emphasis on the global geosciences through a series of interrelated research efforts treating the earth as an integrated system of physical, chemical, and biological processes -- as reported to you by NSF Director Bloch. However, while other U.S. agencies were mentioned as participating, there was no indication that the initiative was "international" in the sense called for by the IGBP concept.

We think close attention should be given to this dimension of the emerging geosciences activities at the NSF. More important, we hope that this Committee will carefully consider how best to use its influence and prestige for bringing the IGBP into being: it could be an achievement of unparalleled importance in the history of human cooperation.

New Perspectives Are Required on Developing Coherent Strategies for Carrying Out International Cooperation -- Including 'Big Science'

Here I must acknowledge and agree with a set of remarks presented by Committee Chairman Don Fuqua at a "Technology Development" Conference in Bonn, West Germany, late in 1984. His thoughtful and provocative comments have probably not received the attention they deserved. His proposition that international cooperation in science and technology must be given greater priority is sound, and I agree wholeheartedly with his statement that the "time has come for it also to become a routine international exercise among nations."

In getting down to the really "hard stuff," Mr. Fuqua goes past the conventional rhetoric that international cooperation is a great goal; he raises some past "unthinkables" -- such as the necesity of giving up on a degree of nationalism in exchange for real collaboration on projects and research facilities, especially those connected with 'big science.' There is no doubt whatsoever in my mind that no nation will be able to afford "going it alone" in building the coming generations of major facilities and projects of a global nature such as the IGBP discussed earlier.

INFRASTRUCTURE ISSUES

The Research Facilities Problem Remains Critical at Universities: Aging Deteriorating, and Terribly Out of Date

Because you held extensive hearings last October on Chairman Fuqua's bill, H.R. 2823, "The University Research Facilities Revitalization Act of 1985," I will not dwell on this sad story today. I would only say that things are just as bad and getting worse. For the record, we would like to note our strong support for H.R. 2823 and hope there will be some forward movement this year.

Even if the G-R-H climate does not permit the allocation of any additional amounts of money this year, it would be quite valuable for the problem to be examined thoroughly and a plan of action devised for such time as when funds might become available. We understand that an NSF report based on last July's meeting at the National Academy of Sciences will be available soon. Perhaps the Subcommittee might wish to consider additional hearings at that time.

The Prospects for Progress in Coping with Research Equipment and Instrumentation Problems Seem Brighter Than Those for Facilities

We strongly support the actions taken by Mr. Bloch in increasing the total NSF allocation for instrumentation and equipment from $223 million in FY 1986 to $260 million in FY 1987. We agree with him that modern research requires state-of-the-art instrumentation and equipment. While the overall requirement remains huge — in the billions -- the FY 87 decision certainly represents some modest progress. We especially appreciate the modest increase for the undergraduate equipment program; we must not forget the entire range of education as I discussed earlier.

MANAGEMENT OF RESEARCH AND DEVELOPMENT ISSUES

There are several areas of concern and questions related to the management of Federal research and development programs which we would like to put on the table. Among these are peer review, indirect costs and the balance of research grants between individual investigators and centers.

There is Growing Controversy About the Manner in Which An Increasing Number of Large Research Grants and Facilities Bypass Peer Review or Even Regular Congressional Review Procedures

There is not time today to discuss our concerns in any detail; however, the trends are sufficiently disturbing to warrant bringing up the subject. In past years, this Subcommittee has provided an enormously valuable contribution by carrying out an extensive series of investigations into peer review. Your reports serve as landmarks.

The concept of peer review of science is a central characteristic of the American system and it is generally acknowledged that this approach accounts for much of the strength of American science. It is with dismay that many of us observe what seems to be increasing attempts -- many of them successful -- to bypass regular peer review processes during the budget allocation proceedings in Congress, or even the Committee-review system itself. Two recent examples illustrate the point I am making:

o In the hectic atmosphere surrounding the windup of its 1985 Session, Congress "earmarked" special research grants for ten universities in the Defense Department's R&D program. The Conference Report on H.J. Resolution 465 -- the continuing appropriations for FY 1986 — included the ten grants, none of which had been through even the Congressional committee review system. By the end of January, only one university, Cornell, had turned down its $10 million allotment of the total $65.5 million package. Ironically, Cornell had applied through normal Defense channels and had not sought the special political assistance given to it, much to its credit.

o A package of amendments to the Higher Education Act (H.R. 3700) contained an array of specially "earmarked" facility authorizations for a number of universities. Regrettably, an amendment to substitute the "earmarking" with a method of distributing such funds competitively was defeated.

It is not that we lack understanding or appreciation of the geographical distribution question for R&D grants, contracts and facilities; my entire statement for you today rests on the premise of the close connection between advances in science and technology with economic and social growth. Moreover, we are fully sympathetic with the near sense of desperation about aging or absent research facilities at many universities, and the desire to stimulate economic development.

But if we, in a time of increasing budget pressures, begin to rush down the path of allocating science resources based largely on "political clout" for individual institutions or grantees, then surely we are at the beginning of undermining faith in our peer review system. This is not a matter of protecting the "haves" of the scientific world; it strikes at the vitality and strength of American science.

Our urgent request to the Subcommittee is that this general topic be placed on your oversight agenda. Your forum can provide an effective place and set of circumstances for addressing these issues, as you have in the past. Achieving a workable set of policies which takes into account the various competing interests would be a major accomplishment.

Reports of OMB Intentions to Impose Uniform Caps on Indirect Costs of Federally-Assisted Research Grants Call for Caution

Again, this is a topic which could tie us up in discussion for days. Indeed, there are not many subjects which have been around longer in the world of Federal support for research and development. But without going into the specifics I would only wish to state the concern of the AAAS that such moves not be taken without timely notice, discussion and adequate transition periods. There are many complexities and contending interests in this area, not only between universities and the Federal Government but also within universities themselves.

The Division of Research Grants Between Individual Investigators and Centers is a Subject Which Requires Systematic Inquiry

A question concerning this matter was raised in your invitation for us to appear today. I regret that we do not now have a satisfactory basis to give you a sensible answer. It is an important policy question, however, and one which deserves a thorough, systematic inquiry. If it is desired by the Subcommittee, the AAAS could undertake at least some preliminary study into the question and submit a report to you at a later date.

Related to this general question is another matter raised in your invitation: what will or should be the relation between the newly proposed NSF biotechnology research centers to those of industry and the work being done under the auspices of NIH. Again, we are not in a position to comment on this evolution, but could perhaps at a later date.

ADDITIONAL NSF BUDGET COMMENTS

While I have discussed previously several aspects of the FY 1987 NSF Budget Request, there are a few more specific comments to offer:

o Overall, the budget is a good one, considering the times.

o I would like to acknowledge the NSF's -- and particularly Director Bloch's — role in the continuing attention and progress on programs for encouraging and supporting scientific and engineering study and careers for women, the disabled and minorities. As an NSF report released at the end of January shows, there have been substantial gains in science and engineering employment for women and minorities since the mid-1970's. Given this success, which can be attributed in part to NSF's pioneering role, we would urge a continuing focus for such areas as:

(1) Being cautious about ill advised or premature mainstreaming of minority-focused programs.

(2) Providing support for minority research centers.

(3) Building a cadre of minority, women and disabled students in science and engineering by early involvement in research; it is possible that this might be encouraged by riders to research grants.

(4) Special training for various NSF program officers as the minority-women-disabled programs become mainstreamed.

o We remain somewhat puzzled by the status of the social and behavioral sciences research. For example, even in such important topics as industrial productivity and innovation, research findings from the social and behavioral sciences frequently are of greater consequence than those from the physical sciences and engineering. We regret that OMB and the NSF do not seem to share this point of view.

We remain concerned about the marginal attention given to the behavioral and social sciences. For example, no special or distinctive statement regarding these vital fields is made in the NSF Budget Summary for FY 1987. I focus on this because these sciences are just beginning to recover from the budgetary beating they took a few years ago.

They are crucial to understanding serious problems in our changing economy, its relation to technological advances, and its demands on education for a transforming workforce. Another crucial problem is conflict resolution in a world full of prejudice, hatred, and violence. Moreover, the past decade has seen a sea change in awareness of the links between health and behavior -- e.g., smoking, alcohol abuse, a variety of damaging drugs, and several major risk factors for heart disease, stroke and cancer.

These three areas of great concern -- the economy, conflict resolution, and health-behavior links -- all illustrate the importance of the behavioral sciences for our future well-being.

o I am pleased that this Subcommittee chose to respond favorably to the many concerns expressed last year about the little program on Ethics and Values in Science and Technology (EVIST). It is also encouraging that Director Bloch has decided to continue sponsoring research in this field. Having said this, I have a small cautionary note: as small programs get distributed throughout the array of NSF directorates and programs, there is the very real risk of a loss of focus. We hope the Subcommittee will continue to monitor this important little area where so many important interdisciplinary studies are done.

CONCLUDING REMARKS

o First, the overall picture of American science and technology is one of apparent health; we invest large amounts of money in R&D. But these amounts must be looked at in comparison to our own needs, the size of our economy and the relative investments by competitors in defense and civilian related areas. There are ample reasons for caution in cutting back or restraining too severely R&D growth, in the G-R-H environment.

o In the realm of basic research, particularly, there is reason for alarm. It is no overstatement to suggest that the American scientific eminence to which Bergstrom referred in his Nobel address is in some danger of eroding.

o The specific budget of the NSF for FY 1987 warrants your strong support. But beyond this budget and this year, and despite the looming G-R-H pressures, I would argue for some slowing down of large, development programs if that becomes necessary to maintain healthy, steady but modest building of the great research-sponsoring agencies of the Federal Government such as the NSF, the National Institutes of Health, and, yes, the Defense Department.

o In making judgments on such support, science policy should place special emphasis on basic research across the entire spectrum of the sciences; it is from such research that the companies and industries of the 21st Century will arise. In this context, we must foster the continuing interplay of basic and applied sciences so that each may stimulate the other. Special attention must also be devoted to creating and encouraging an environment for cooperation among government laboratories, universities, and industry.

o We strongly support the Administration's drive to provide incentives for industry to strengthen research and development across the board, not only in the obviously high-tech industries. Building a bipartisan consensus for support in this area is a high priority.

o Strengthening basic research in the field of agriculture is important to our well-being, our health, and our role in the world. Our big problem here is that we have done so well that complacency can become a danger. (Indeed, the same could be said for health research.) But there are issues that deserve our sustained attention: massive soil erosion, looming water shortages and contamination, decrease in the genetic variability of plant life, and the uncertain role of the new biotechnologies with regard to agriculture.

o The oil glut is temporary. The basic facts have not changed. The long-run supply is seriously limited and many of the sources are politically volatile. We cannot set aside research on conservation and alternative energy sources. We must take a long view of the fact that the United States is the most energy-intensive nation in the world today and that others are moving rapidly in this direction.

o We must undertake and support a variety of measures, including stronger support for education, to provide distinctive opportunities for young people to participate effectively in this emerging scientific and technological age. These opportunities should be available regardless of race, gender, or religion.

o Finally, and this is nothing new to this Committee since you are in the midst of a major science policy review, it is increasingly important that eventually we face the need for better governmental and private mechanisms in science policy formulation: we must do a better job of analyzing and appraising the various options and policy measures embedded in just the short list of issues I have reviewed — and it is by no means complete. This general need becomes even more acute as we contemplate the growing international and global dimensions which I have discussed only briefly in my statement.

MAJOR RECOMMENDATIONS

1. Provide strong support for the NSF Budget as proposed. While our differences with the NSF on education are significant, they do not translate into specific budget comments this year. We would hope that the Subcommittee will use its good offices to speed up the planning process at NSF. For the longer term, a growing role for the NSF in science education will be crucial.

2. Focus attention on the newly emerging dimensions of international science and technology — ranging from a more pronounced role for the NSF to the considerations for establishing one or more major global cooperative

efforts. The International Geosphere-Biosphere Program (IGBP) seems to be a likely candidate.

3. Give special attention in international science and technology to Chairman Fuqua's ideas for intensive examination of more effective ways to collaborate on research projects and facilities.

4. Carefully monitor the NSF commitment to the behavioral and social sciences.

5. Consider an up-dated oversight examination of peer review, particularly in light of several trends discussed briefly in my statement.

6. In possible next phases of the Committee's Science Policy Task Force, consider a number of the policy issues noted above — particularly that dealing with new institutional ways to accomplish the required policy analysis.

7. Finally, in the turbulent times ahead as you deal with the political ramifications of deficit reduction, please consider the investment character of research and development -- particularly, basic research.

APPENDIX 1

Trends in Federal and non-Federal R&D outlays: 1953 and 1960-86
[Percents]

Year	Total	Federal Defense Related	Space Related	Civilian Related	Non-Federal	Total National (Constant) Dollars (1982)	Total National (Current) Dollars
1953	54	48	1	5	46	$ 19,744	$ 5,124
1960	65	52	3	9	35	43,648	13,523
1961	65	50	6	9	35	45,764	14,316
1962	64	48	7	9	36	48,176	15,394
1963	66	41	14	11	34	52,585	17,059
1964	66	37	20	9	34	57,202	18,854
1965	65	33	21	11	35	59,351	20,044
1966	64	33	19	12	36	62,589	21,846
1967	62	35	14	13	38	64,406	23,146
1968	61	35	13	13	39	65,458	24,605
1969	58	34	11	13	42	64,672	25,631
1970	57	33	10	14	43	62,405	26,134
1971	56	32	9	15	44	60,385	26,676
1972	56	32	9	15	44	61,414	28,477
1973	53	30	8	15	47	62,427	30,718
1974	51	27	8	16	49	61,467	32,864
1975	51	26	8	17	49	59,885	35,213
1976	51	26	8	17	49	62,134	39,018
1977	50	25	8	17	50	63,653	42,783
1978	50	24	7	19	50	66,769	48,129
1979	49	23	7	19	51	70,077	54,933
1980	47	22	7	18	53	73,235	62,593
1981	46	23	7	16	54	76,610	71,840
1982	46	25	7	14	54	79,328	79,328
1983 est.	47	27	7	13	53	83,862	87,178
1984 est.	47	29	6	12	53	89,937	97,275
1985 est.	47	30	6	11	53	97,283	108,800
1986 est.	47	30	7	10	53	$102,504	$118,600

NOTE: Detail may not add to 100 percent because of rounding.
SOURCE: National science Foundation

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APPENDIX 2

National Expenditures for Performance of R&D as Percent of Gross National Product (GNP) by Country: 1961-86

YEAR	FRANCE	WEST GERMANY	JAPAN	UNITED KINGDOM	UNITED STATES	U.S.S.R.
1961	1.37	NA	1.39	2.47	2.68	NA
1962	1.47	1.25	1.47	NA	2.68	2.64
1963	1.55	1.41	1.44	NA	2.81	2.80
1964	1.81	1.57	1.48	2.30	2.90	2.87
1965	2.00	1.72	1.52	NA	2.84	2.85
1966	2.07	1.81	1.46	2.32	2.83	2.88
1967	2.12	1.96	1.52	2.30	2.84	2.91
1968	2.08	1.98	1.60	2.26	2.76	NA
1969	1.93	1.82	1.64	2.27	2.66	3.03
1970	1.92	2.06	1.85	NA	2.57	3.28
1971	1.90	2.18	1.85	NA	2.42	3.46
1972	1.90	2.20	1.86	2.11	2.40	3.71
1973	1.77	2.09	1.90	NA	2.26	3.81
1974	1.79	2.13	1.97	NA	2.23	3.74
1975	1.80	2.22	1.96	2.19	2.20	3.78
1976	1.78	2.15	1.95	NA	2.19	3.61
1977	1.76	2.14	1.93	NA	2.15	3.54
1978	1.76	2.24	2.00	2.24	2.14	3.54
1979	1.81	2.40	2.09	NA	2.19	3.59
1980	1.84	2.42	2.22	NA	2.29	3.76
1981	2.01	2.49	2.38	2.41	2.35	3.75
1982	2.10	2.58	2.47	NA	2.51	3.68
1983	2.15	2.52	2.61	2.24	2.56	3.82
1984 prel.	2.24	2.52	2.60	NA	2.58	3.95
1985 est.	2.27	2.61	NA	NA	2.72	NA
1986 est.	NA	NA	NA	NA	2.76	NA

SOURCE: National Science Foundation, Organization for Economic Cooperation and national country sources.

APPENDIX 3

Estimated Ratio of Civilian R&D Expenditures[1] to Gross National Product (GNP) for Selected Countries: 1967-85

YEAR	FRANCE	WEST GERMANY	JAPAN	UNITED KINGDOM	UNITED STATES
1967	NA	NA	1.51	NA	1.88
1968	NA	1.80	1.59	NA	1.83
1969	NA	1.87	1.63	NA	1.79
1970	NA	2.01	1.79	NA	1.76
1971	1.5	2.0	1.8	NA	1.6
1972	1.5	2.1	1.8	1.5	1.6
1973	1.4	2.0	1.9	NA	1.6
1974	1.4	2.0	2.0	NA	1.6
1975	1.5	2.1	1.9	1.4	1.6
1976	1.4	2.0	1.9	NA	1.6
1977	1.4	2.0	1.9	NA	1.6
1978	1.4	2.1	2.0	1.5	1.6
1979	1.4	2.3	2.1	NA	1.7
1980	1.4	2.3	2.2	NA	1.8
1981	1.5	2.4	2.4	1.7	1.8
1982	1.6	2.5	2.5	NA	1.9
1983	1.7	2.4	2.6	1.6	1.9
1984 est.	1.8	2.4	2.6	NA	1.8
1985 est.	NA	2.5	NA	NA	1.9

[1] National R&D expenditures, excluding government funds for defense.
N/A = Not available.
SOURCES: National Science Foundation and Organization for Economic Cooperation and Development.

Mr. **Walgren**. Thank you very much, Dr. Hamburg. We appreciate that testimony very much, and it was well done.

Dr. Rosenzweig?

Dr. **Rosenzweig**. Thank you very much, Mr. Chairman. I, too, appreciate the chance to discuss with you this year's National Science Foundation budget. It is a special treat, I should say, to appear on the same panel with my old friend and colleague, Dave Hamburg. It is the second year in a row that you have given me that opportunity, and it gives me a chance to say hello to David, too.

I cannot recall a year in which the budgetary matters were so filled with uncertainty and in which the whole process seemed headed for a destination that no one in it could foresee, and in which the possibility of serious damage to important social institutions seems so real.

It is against that backdrop, Mr. Chairman, that I want to discuss the fiscal year 1987 NSF budget. If this were just another year, I would, as in previous years, address that budget as if it stood alone and could be dealt with substantially without regard to other matters which you, as Members of Congress, will confront.

In this year, however, I don't believe that the NSF budget, or perhaps any other, can be considered by a congressional committee without regard to responsibilities of Members that go beyond their subcommittee and committee assignments and the agencies within their jurisdiction. In the few minutes I have, I would like to elaborate on that point.

I have submitted for the record, Mr. Chairman, a formal statement which deals with the specifics of the President's proposed budget. It is, in all important respects, an excellent budget for NSF. In its totality it constitutes an affirmation of the importance of university-based science and technology.

In its specifics it shows good balance between science and engineering and a welcome recovery of the Foundation's role in science education. All in all, if this were an ordinary year, with this budget before us, you would not hear much but good cheer from me and my member universities.

As I have said, though, this is not an ordinary year. What marks it off from others, it seems to me, is the pervasive sense of vulnerability that makes even good news suspect. Universities feel that vulnerability keenly because several essentially unrelated policy lines seem to be converging, and if they truly do meet, then there is the real prospect of very serious damage to those institutions and to the intellectual activity for which they are responsible.

Let me briefly describe those lines and explain why they should be of interest to Members whose responsibilities include the maintenance of America's capacity for science and science education.

The first set of policies to impinge on universities are those set in motion by deficit reduction pressures. NSF stands out among Federal agencies for its proposed increase for fiscal year 1987. That very fact may make it vulnerable as it moves through the Congress, but the main point is that virtually every other program on which universities rely is slated for significant reductions.

The proposed cuts in student aid, in the NIH budget, and in Medicare and Medicaid reimbursement will strike heavy blows at mainline university activities, and will force either reductions in institutional programs or the increased subsidizing of those activities by other elements in the institution.

Second, the proposed revisions to OMB circular A-21, just published, which would cap particular components of indirect cost recovery, will hit the budgets of research universities heavily.

If those rules take effect as proposed, losses in the millions of dollars a year will be incurred by individual institutions, and virtually all universities will suffer noticeable reductions.

In part, the new rules are prompted by the deficit pressures, but, in fact, the impetus for them predates the present crisis and really derives from a deeply held belief by some that the costs of research that can be associated with an individual project are somehow more real and important than are those costs that need to be pooled and allocated to all projects.

That may sound to you, as it frequently does to me, like a rather arcane bit of accounting theology, but unfortunately the effect of policies based upon it would be to starve the body while expecting the brain to continue to function. That is a policy that will not work for long.

The third line of policy, Mr. Chairman, that is converging on universities makes the effect of the first two even more devastating. The tax reform bill that passed the House last year contains a number of provisions that will simultaneously cost universities more money and severely undermine their ability to raise money from private philanthropy.

I will not take time this morning to describe the problems in that legislation. I will simply say that the deliberations that led to the passage of the House bill did not include considerations of education or science policy, but the effect of the provisions adopted must be taken into account by anyone who cares about the health of America's universities or the Nation's capacities in science and technology.

Now, let me make it clear that none of the university presidents I know claims a special educational exemption from the solution of the Nation's fiscal problems, nor do they ascribe these problems to some dark, antiuniversity conspiracy.

All would, I think, argue that the combination of circumstances I have described exposes universities to special and largely unintended jeopardy, and they would wish that important fact to be considered by those who make policy for the Nation.

The question you have a right to ask is, what is to be done, as Lenin said? The answers for this year are clear enough, and you will surely be hearing them repeated in the coming months. They are, where possible, as with NSF, to support budget levels that will help sustain the enterprise through a difficult period; to help prevent arbitrary, damaging, and nonnegotiated changes in the principles that govern indirect cost recovery by urging OMB to withdraw the proposed revision and enter into genuine consultations with the affected parties; and to oppose changes in the Tax Code that would lessen the incentives for private philanthropy and therefore make it less likely that private efforts can compensate for the inevitable diminution in Federal programs.

That is the immediate program, and it is an important one. But I submit that it is not enough. If we are to achieve solutions to our current problems that will not just provide immediate relief but will also lay the foundation for sustained national health, then I submit that it will help to begin to think of national budgeting in more than arithmetic terms.

We do not put together budgets in private or public life in order to have them balance at the end. What happens at the end is the result of a complex set of judgments about what we need and what we can afford.

In all organizations except Government, we distinguish between expenditures for current use and investments aimed at future return. Without that elementary distinction it is impossible to make analytical sense out of our national accounts or to know whether we are spending too much or too little. And if we are unable to do that, it is hardly any wonder that we are unable to come to grips with the question of how much money we need to raise as a Nation in order to meet the demands of the present and the needs of the future.

In that last sentence lies the key element in your efforts to find a broad and solid base for the future productivity of basic scientific and engineering research and training and of the institutions in which those take place.

In my personal view, Mr. Chairman, there is no coherent and realistic program for meeting the Nation's real needs that does not take a hard look at revenues along with expenditures. When all is said and done, we are not paying for what we need, and any solution that does not confront that fact will, in the end, do more harm than good.

I am aware, Mr. Chairman, that I have gone rather far afield from the testimony that one would ordinarily give on this occasion. I have done that because it seems to me evident that when you finish work on this NSF budget, you will, as Members of Congress, face an agenda that is even more important to science and to universities than the annual budget of any single agency can be. As you approach those larger issues, I urge you to bring to them the same purposes and perspectives that move you to believe that the work of the National Science Foundation is worth your support. More than at most times, this year's motto must be: One war, many fronts.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Rosenzweig follows:]

PREPARED STATEMENT OF DR. ROBERT M. ROSENZWEIG

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE:

I APPEAR THIS MORNING ON BEHALF OF FIVE ASSOCIATIONS OF UNIVERSITIES AND COLLEGES. TOGETHER, THEY REPRESENT ESSENTIALLY ALL OF THE INSTITUTIONS OF HIGHER EDUCATION THAT CONDUCT FEDERAL RESEARCH AND RELATED EDUCATION PROGRAMS. WE APPRECIATE THE OPPORTUNITY TO OFFER THE FOLLOWING BRIEF COMMENTS ON THE FY 1987 AUTHORIZATION FOR THE NATIONAL SCIENCE FOUNDATION.

RESEARCH

FIRST, WE CONGRATULATE MR. BLOCH, DIRECTOR OF THE FOUNDATION, AND THE NATIONAL SCIENCE BOARD FOR, ONCE AGAIN, PRESENTING TO THE CONGRESS A STRONG, REASONABLE AND GENERALLY WELL-BALANCED BUDGET FOR THE NATIONAL SCIENCE FOUNDATION. THE NSF BUDGET REQUEST FOR FY 1987 RECOGNIZES CLEARLY THAT EVEN IN THESE DIFFICULT TIMES, WE CANNOT AFFORD TO REDUCE OUR INVESTMENT IN ACADEMIC SCIENCE AND ENGINEERING. SUSTAINED BUDGETARY STRINGENCY REQUIRES THAT WE MAKE DIFFICULT CHOICES. IN MAKING THESE CHOICES WE MUST SUSTAIN INVESTMENT IN THE PRODUCTION OF THE TWO INGREDIENTS ESSENTIAL TO OUR TECHNOLOGICAL DEVELOPMENT, OUR ECONOMIC COMPETITIVENESS, OUR NATIONAL SECURITY AND OUR HEALTH: THE TALENT OF OUR YOUNG PEOPLE AND OUR EXPANDING BODY OF NEW KNOWLEDGE. WE MUST PROVIDE FOR CONTINUED INVESTMENT IN THE EDUCATION OF OUR YOUNG MEN AND WOMEN, AND TAKE THOSE NECESSARY STEPS TO ENCOURAGE ABLE AND INTERESTED

STUDENTS, ESPECIALLY UNDERREPRESENTED MINORITIES AND WOMEN, TO PURSUE UNDERGRADUATE AND GRADUATE PROGRAMS IN ACADEMIC SCIENCE AND ENGINEERING.

MR. BLOCH APPEARED BEFORE THIS SUBCOMMITTEE ON FEBRUARY 20. HE EMPHASIZED THAT LONG AGO WE RECOGNIZED THE UNIQUE BENEFITS THAT RESULT WHEN NATIONAL INVESTMENTS IN EDUCATION AND RESEARCH ARE COMBINED IN THE UNIVERSITY ENTERPRISE. (NOW MORE THAN HALF OF ALL FEDERAL BASIC RESEARCH PROGRAMS ARE CARRIED OUT IN UNIVERSITIES AND COLLEGES; NSF ACCOUNTS FOR 25% OF TOTAL FEDERAL BASIC RESEARCH FUNDING IN UNIVERSITIES.) WHEN STUDENTS WORK WITH FACULTY TEAMS ENGAGED IN NATIONAL COMPETITIVE RESEARCH PROGRAMS, RESEARCH AND EDUCATION BECOME THE SAME ACTIVITY. THAT BOND FORGED BETWEEN EDUCATION AND RESEARCH IS ITSELF THE UNIQUE STRENGTH OF ACADEMIC SCIENCE AND ENGINEERING. WE ARE ENCOURAGED THEREFORE TO SEE THAT NSF PROPOSES TO FURTHER EXPAND INVOLVEMENT OF GRADUATE AND UNDERGRADUATE STUDENTS IN MANY OF ITS RESEARCH PROGRAMS. (IN FY 1987 NSF ESTIMATES THAT 13,100 (+7%) GRADUATE STUDENTS, 4,500 (+25%) UNDERGRADUATE STUDENTS AND 3,700 (+4%) POSTDOCTORAL STUDENTS WILL BE PARTICIPATE AS RESEARCH PERSONNEL ON NSF RESEARCH GRANTS.)

AS THE PROMISING AND IMPORTANT INITIATIVES ANNOUNCED BY THE FOUNDATION GO FORWARD, IT WILL BE IMPORTANT TO KEEP A CLOSE EYE ON THE CORE ACTIVITY OF THE FOUNDATION -- THE INDIVIDUAL INVESTIGATOR GRANT. THE BUDGET REQUEST FOR RESEARCH AND RELATED PROGRAMS GIVES SPECIAL EMPHASIS TO BIOTECHNOLOGY, COMPUTATIONAL

SCIENCE AND ENGINEERING AND GLOBAL GEOSCIENCES. THE CROSS-DISCIPLINARY ENGINEERING RESEARCH CENTERS (ERC) PROGRAM PROPOSES TO CREATE UP TO FIVE NEW UNIVERSITY CENTERS JOINTLY FUNDED WITH INDUSTRY. THE ADVANCED SCIENTIFIC COMPUTING ACTIVITY WILL BE STRENGTHENED, ALTHOUGH NO NEW CENTERS ARE PROPOSED. AS PRESENTED, THE BUDGET SUSTAINS INVESTMENT IN COMPETITIVE AWARDS TO INDIVIDUAL RESEARCHERS. IT SEEKS TO PROTECT PROGRESS MADE IN RECENT YEARS TO STRENGTHEN THE AVERAGE SIZE AND DURATION OF FOUNDATION GRANTS. WE TRUST THAT THESE GAINS WILL NOT BE COMPROMISED BY THE DEVELOPMENT OF THE EXCITING NEW INITIATIVES.

WE ARE PLEASED TO SEE THAT THE SOCIAL AND BEHAVIOR SCIENCES PROGRAMS HAVE RECLAIMED THEIR APPROPRIATE PLACE IN THE NSF RESEARCH BUDGET. THE SHARP REDUCTIONS IMPOSED JUST A FEW YEARS AGO ARE RESTORED. THIS REFLECTS AN APPROPRIATE RECOGNITION OF THE POTENTIAL CONTRIBUTION OF RESEARCH IN THESE FIELDS TO OUR PRODUCTIVITY AND SECURITY.

WE WOULD CALL TO THE COMMITTEE'S ATTENTION ONE POTENTIALLY ANOMALOUS ASPECT OF THE BUDGET REQUEST: THE REQUEST FOR ASTRONOMICAL SCIENCES. MEMORIES ARE FRESH AND PAINFUL OF THE CONSEQUENCES OF EXTREME BUDGET FLUCTUATIONS EXPERIENCED BY THE SOCIAL AND BEHAVIORAL SCIENCES JUST A FEW YEARS AGO. NOW WHEN MOST RESEARCH PROGRAMS ARE SLATED TO RECEIVE AT LEAST A MEASURE OF REAL GROWTH, A REDUCTION IN CONSTANT DOLLARS IS PROPOSED FOR THE ASTRONOMICAL SCIENCES. BECAUSE THE NASA ASTRONOMICAL SCIENCES BUDGET ALSO IS UNDER CONSIDERABLE STRAIN THIS YEAR, WE BELIEVE IT

IS TIMELY TO INQUIRE ABOUT THE COMBINED CONSEQUENCES FOR UNIVERSITY ASTRONOMICAL SCIENCES PROGRAMS OF SUCH A SHARPLY CONSTRAINED BUDGET REQUEST. WE HOPE THAT THE COMMITTEE WILL REVIEW CAREFULLY THE REQUEST FOR THE ASTRONOMICAL SCIENCES PROGRAM IN THE CONTEXT OF THE PROSPECTS FOR TOTAL FEDERAL SUPPORT FOR THE FIELD.

GRADUATE FELLOWSHIPS

AGAIN THIS YEAR THE GRADUATE FELLOWSHIP PROGRAM IS LEVEL FUNDED. WE UNDERSTAND THAT ABOUT 560 NEW AWARDS ARE PLANNED WITH A STEADY STATE OF 1500 COMPETITIVE FELLOWSHIPS. NO ADJUSTMENT IN THE STUDENT STIPEND IS PROPOSED. AFTER MAKING PROGRESS TOWARD OVERCOMING THE EFFECTS OF A DECADE OF EROSION THE PROGRAM AGAIN IS BEGINNING TO LAG SIGNIFICANTLY BEHIND MARKET FORCES COMPETING FOR THE BEST YOUNG UNDERGRADUATE MINDS IN SCIENCE AND ENGINEERING. THE NSF PROGRAM CONTINUES TO PROVIDE STIPENDS THAT ARE SUBSTANTIALLY BELOW THE SMALL (40-50 AWARDS PER YEAR) COMPETITIVE PROGRAM OF THE OFFICE OF NAVAL RESEARCH (ONR). THE ONR PROGRAM PROVIDES A FIRST-YEAR STIPEND OF APPROXIMATELY $13,000 PER YEAR, FULL TUITION AND A SUPPLEMENTAL RESEARCH AWARD TO DEPARTMENTS SELECTED BY EACH ONR FELLOW.

FOR MORE THAN A DECADE THE COST OF EDUCATION ALLOWANCE HAS FALLEN STEADILY BEHIND THE ACTUAL COST OF GRADUATE EDUCATION IN THE SCIENCES AND ENGINEERING. THIS YEAR, WE UNDERSTAND THAT THE NSF PROGRAM WILL TAKE A STEP BACKWARDS BY REDUCING THE COST OF EDUCATION ALLOWANCE (NOW ONLY $6,000) THAT ACCOMPANIES EACH NSF

FELLOWSHIP. RATHER THAN COVER EVEN THE COST OF TUITION, WHICH ITSELF DOES NOT COVER THE ACTUAL COSTS OF INSTRUCTION, THE NSF PROGRAM CONTINUES TO REQUIRE HOST UNIVERSITIES TO SUBSIDIZE THE PROGRAM FROM THEIR OWN FUNDS AND TO DO SO BY IN STEADILY INCREASING AMOUNTS. THIS REMAINS A TROUBLESOME AND GROWING INEQUITY IN THE PROGRAM.

WE UNDERSTAND THAT THE FOUNDATION PROPOSES TO ABSORB THE REDUCTIONS REQUIRED BY THE GRAMM/RUDMAN/HOLLINGS BALANCED BUDGET ACT BY ABSORBING THE ENTIRE REDUCTION IN THE COST OF EDUCATION ALLOWANCE. THIS STEP IS INCONSISTENT WITH RECENT ATTEMPTS TO BRING THE PROGRAM INTO LINE WITH PRESENT COSTS. WE URGE THE COMMITTEE TO ASK THE FOUNDATION TO SUSTAIN AT LEAST PRESENT FUNDING LEVELS FOR THE COST OF EDUCATION ALLOWANCE.

UNDERGRADUATE SCIENCE AND ENGINEERING EDUCATION

THE NSF PROPOSES A MODEST INCREASE FOR SCIENCE AND ENGINEERING ACTIVITIES. WITH THE EXCEPTION OF THE COLLEGE SCIENCE INSTRUMENTATION PROGRAM WHICH IS INCREASED BY $2 MILLION IN ORDER TO FUND BETWEEN 75 AND 80 NEW PROJECTS, ALL PROGRAMS ARE MAINTAINED AT THEIR FY 1986 LEVEL. THE PROBLEMS ASSOCIATED WITH OBSOLETE RESEARCH INSTRUMENTATION AND INSTRUCTIONAL EQUIPMENT ARE WELL KNOWN TO THE COMMITTEE ON SCIENCE AND TECHNOLOGY. ALTHOUGH WE ARE PLEASED TO SEE AN EXPANDED COMMITMENT TO ADDRESSING THIS AREA, ESPECIALLY IN OUR SCHOOLS OF ENGINEERING, THE PRESENT PROGRAM LEVEL IS ONLY A FIRST STEP.

RECENTLY, AT THE REQUEST OF THE DIRECTOR OF THE FOUNDATION, THE AMERICAN COUNCIL ON EDUCATION, IN CONJUNCTION WITH SEVERAL OTHER ASSOCIATIONS APPOINTED A SPECIAL TASK FORCE OF COLLEGE PRESIDENTS TO ESTABLISH A CONSENSUS ON PRIORITIES FOR NSF LEADERSHIP AND SUPPORT FOR UNDERGRADUATE SCIENCE AND EDUCATION. WE ARE PLEASED TO PRESENT THESE RECOMMENDATIONS TO THE SUBCOMMITTEE. THE REPORT IS APPENDED (ATTACHMENT). FOR YOUR CONVENIENCE THE FOLLOWING IS AN ABBREVIATED SUMMARY OF THE TASK FORCE'S RECOMMENDATIONS:

A. INCREASE PARTICIPATION OF THE UNDERGRADUATE SECTOR IN NSF ACTIVITIES.

- STRENGTHEN LINKS WITH UNDERGRADUATE INSTITUTIONS
- INVOLVE MORE FACULTY FROM NON-DOCTORAL INSTITUTIONS IN PANELS AND AS MEMBERS OF THE NATIONAL SCIENCE BOARD

B. STRENGTHEN NSF LEADERSHIP IN SCIENCE AND ENGINEERING EDUCATION

- EXPAND SUPPORT FOR RESEARCH AT UNDERGRADUATE INSTITUTIONS
- ALLOCATE AN INCREASED SHARE OF RESEARCH FUNDS TO INVESTIGATORS IN UNDERGRADUATE INSTITUTIONS
- ENCOURAGE INVESTIGATORS IN UNDERGRADUATE INSTITUTIONS TO COMPETE FOR RESEARCH AWARDS

C. ASSIGN FIRST PRIORITY TO UNDERGRADUATE INSTRUCTIONAL

EQUIPMENT AND MATERIALS

- SUBSTANTIALLY EXPAND THE COLLEGE SCIENCE INSTRUMENTATION PROGRAM
- MAKE AWARDS COMPETITIVELY
- PERMIT INSTITUTIONS TO APPLY EXPENDITURES FOR INSTALLATION AND MAINTENANCE TO THEIR MATCHING REQUIREMENT
- ENSURE THAT INSTITUTIONS AWARDED FUNDS PROVIDE FOR PROPER MAINTENANCE OF FUNDED EQUIPMENT
- EXPAND ELIGIBILITY FOR SUPPORT OF DEVELOPMENT AND APPLICATION OF INSTRUCTIONAL TECHNOLOGY TO IMPROVE THE QUALITY OF INSTRUCTION IN THE SCIENCES
- ASSIST NEW AND EMERGING SCIENCE PROGRAMS
- ENCOURAGE TECHNOLOGY TRANSFER AMONG UNDERGRADUATE INSTITUTIONS

D. ASSIGN SECOND PRIORITY TO FACULTY AND STUDENT NEEDS

- EXPAND SUPPORT FOR UNDERGRADUATE RESEARCH ACTIVITIES ACROSS ALL RESEARCH DIRECTORATES
- EXPAND OPPORTUNITIES FOR UNDERGRADUATE FACULTY UNDER THE TEACHER ENHANCEMENT AND INFORMAL SCIENCE EDUCATION PROGRAM

E. AS AN ADDED DIMENSION UNDERTAKE TWO SPECIAL INITIATIVES:

- ESTABLISH A LIMITED NUMBER OF CONSORTIA AS CENTERS OF INSTRUCTIONAL EXCELLENCE IN UNDERGRADUATE SCIENCE,

ENGINEERING AND TECHNICAL PROGRAMS

-ESTABLISH A PROGRAM OF CHALLENGE GRANTS TO ENCOURAGE AND ASSIST INSTITUTIONS TO SET INSTRUCTIONAL OBJECTIVES, ARTICULATE NEEDS AND DEVELOP PLANS

INSTRUMENTATION AND FACILITIES

THE FOUNDATION HAS MADE SUBSTANTIAL PROGRESS IN IDENTIFYING AND MEETING THE RESEARCH INSTRUMENTATION NEEDS OF FOUNDATION-FUNDED INVESTIGATORS. NOW ABOUT 20% OF TOTAL NSF RESEARCH FUNDS ARE ALLOCATED TO THE ACQUISITION OF RESEARCH EQUIPMENT. WE COMMEND THE CONGRESS AND THE FOUNDATION FOR SUSTAINING A STRONG COMMITMENT TO ADDRESSING THE RESEARCH EQUIPMENT PROBLEM.

WE MUST POINT OUT, HOWEVER, THAT LITTLE PROGRESS HAS BEEN ACHIEVED IN MEETING THE NEEDS OF RESEARCH INSTITUTIONS TO REPLACE AND MODERNIZE LABORATORIES IN WHICH NATIONAL RESEARCH PROGRAMS ARE CONDUCTED.

LAST YEAR CHAIRMAN FUQUA INTRODUCED H.R. 2823, THE UNIVERSITY RESEARCH FACILITIES REVITALIZATION ACT OF 1986. THE BILL PROVIDES FOR A COMPREHENSIVE, GOVERNMENT-WIDE, SUSTAINED PROGRAM IN SIX LEADING AGENCIES. THE BILL IS A COMMENDABLE STARTING POINT AND A VEHICLE FOR FURTHER DEBATE ON THE PROBLEM. WE AGAIN EXPRESS TO CHAIRMAN FUQUA AND THE OTHER MEMBERS OF THE HOUSE WHO HAVE JOINED WITH HIM IN THIS EFFORT OUR APPRECIATION FOR BRINGING

MUCH NEEDED ATTENTION TO THIS PROBLEM. THE HEARINGS HELD BY THE COMMITTEE ON SCIENCE AND TECHNOLOGY LAST YEAR PROVIDED THE FIRST SUSTAINED ATTENTION BY THE CONGRESS TO THIS PROBLEM IN MANY YEARS. THE INTRODUCTION OF H.R. 2823 AND THE ACTIVITIES OF THE COMMITTEE ARE VALUABLE CONTRIBUTIONS TOWARD A SEARCH FOR ACCEPTABLE APPROACHES.

WE UNDERSTAND THAT THE WHITE HOUSE SCIENCE COUNCIL IS CONSIDERING A RECOMMENDATION THAT THE NATIONAL SCIENCE FOUNDATION UNDERTAKE A RESEARCH FACILITIES MODERNIZATION PROGRAM. WHILE WE RECOGNIZE THE PRESENT BARRIERS TO MAKING PROGRESS TOWARD PROGRAMMATIC SOLUTIONS, WE ARE ENCOURAGED THAT THE GENERAL CHARACTERISTICS OF THE PROBLEM, ITS SERIOUSNESS AND A FEDERAL RESPONSIBILITY TO HELP FASHION SOLUTIONS ARE NOW MORE WIDELY RECOGNIZED. WE ALSO ARE ENCOURAGED THAT THE FOUNDATION, AS DIRECTED BY THE CONGRESS LAST YEAR, IS DEVELOPING A CAPABILITY TO ASSESS THE PROBLEM IN A COMPREHENSIVE WAY. WE HOPE THAT THIS COMMITTEE WILL GIVE THE FACILITIES PROBLEM FURTHER ATTENTION WHEN THE FIRST NSF REPORT IS COMPLETED LATER THIS YEAR.

WE THANK THE COMMITTEE FOR THE OPPORTUNITY TO PRESENT THESE VIEWS.

Mr. WALGREN. Thank you, Dr. Rosenzweig.

I am sure those themes are directly relevant to everyone's concerns, and you need not worry that addressing the larger questions seems not to respond to the narrow ones at all in this arena today.

Let's turn, then, to Dr. Krauss.

Dr. KRAUSS. Mr. Chairman, and members of the subcommittee, I appreciate very much the opportunity to present the views of FASEB to you today, dealing with the authorizing legislation and the President's fiscal year 1987 budget proposal for the National Science Foundation.

A moment of orientation: FASEB, the Federation of American Societies for Experimental Biology, contains seven constituent societies representing biomedical and biological disciplines in research, educational and clinical centers across the United States. Since our founding in 1912, we have counted 108 Nobel Prize winners among our membership.

The Federation supports the President's fiscal year 1987 budget request for the Foundation of $1.686 billion, a 13.2-percent increase over the fiscal year 1986 Gramm-Rudman adjusted level of $1.489 billion. Now, we are pleased to note that, of the proposed fiscal year 1987 total, $1.479 billion is provided for research and related activities.

However, we are concerned that funding for NSF and the activities it supports not reach a plateau or decrease. For fiscal year 1986 this subcommittee approved the 4.5-percent increase in NSF funding requested by the administration. But the appropriations history shows that from fiscal year 1985 to fiscal year 1986, NSF funding increased by less than 2 percent, less than the rate of inflation.

When Gramm-Rudman sequestrations are applied to NSF's fiscal year 1986 current plan of $1.523 billion, fiscal year 1986 NSF funding would drop $12 million below the fiscal year 1985 level. In spite of these disturbing figures, NSF has fared at this stage better than other nondefense segments of the fiscal year 1987 research and development budget request.

The Federation wishes the administration fiscal year 1987 budget had been equally generous to other areas of basic research. We were deeply disturbed by the President's proposed cut in the National Institutes of Health budget, including shifting AIDS funding to another agency.

The cut could range from $424 million to more than a half billion dollars below the fiscal year 1986 congressional appropriation.

In addition, funding for alcohol, drug abuse, and mental health research would fall about $17 million below the congressionally approved fiscal year 1986 level. Competitive research grants at the U.S. Department of Agriculture also would drop below the fiscal year 1986 level approved by Congress. The NSF budget must be viewed in the context of the very severe cuts in allied research at NIH and elsewhere.

FASEB is fully aware of the need to balance the Federal budget and of the fiscal implications continued high deficits have for the future of all Federal programs. But science is in a somewhat different position than many other Federal programs. Biomedical research is a long-term investment and there is little or no possibility of substantial help from State and local government in this investment.

There is some assistance from the private sector, but clearly it is the Federal Government which will continue to be the main source for the financial support for the disease-oriented research carried out by the NIH as well as the basic research funded by the National Science Foundation.

In this circumstance, there can be no justification for cutbacks in biological and biomedical research funding in fiscal year 1987, particularly at a time when many important research opportunities await us in such areas as molecular biology, immunology, and neuroscience. This research is vital to the control and eradication of major diseases, will improve human life, and will help to maintain our competitive edge as the world leader in biomedical research.

A part of this Federal investment in research includes recruiting and training the next generation of scientists. The Federation is pleased that NSF's request for fiscal year 1987 includes $89 million for the science and engineering education activity.

As you know, the $87 million of fiscal year 1986 funds for science education included a $31.5 million carryover from fiscal year 1985. The fiscal year 1987 request builds that $31.5 million back into the base request for SEE, an important step toward maintaining this program at a steady funding level.

FASEB has a particular interest in this NSF activity. Part of the Federation's mission as an organization is the dissemination of knowledge in the life sciences. In a recent interview published in our journal, a biology teacher who received an NSF 1985 Presidential Award for Excellence in Science and Math Teaching said: "Young children in our society have lost their interest in science by the time they get to intermediate school."

This dedicated teacher has developed her own program to attract young, inquisitive minds to science in general and research careers in particular, but we need to multiply that effort many times over to assure a continuing supply of promising young people for our field.

FASEB also supports at least the proposed fiscal year 1987 budget level of $282 million for the Biological, Behavioral and Social Sciences Directorate, an 8.5-percent increase over the planned fiscal year 1986 level of $260 million.

Within BBS all biology programs would show growth: Molecular biosciences up 8 percent, cellular biosciences up 9 percent, and biotic systems and resources up 9 percent.

Steady and sufficient Federal support of the basic life sciences not only assures aspiring scientists of the viability of a career in scientific inquiry, but is essential to preserve the momentum of research at a time when the scientific community is poised to take advantage of significant opportunities in a number of the biology-related areas.

We are glad that NSF has recognized one of those key disciplines by designating biotechnology as one of the three areas of extraordinary scientific opportunity. In fiscal year 1987, the proposed budget includes a $20 million increment to the current fiscal year 1986 level of $86.5 million. These funds would support multidisciplinary biotechnology centers and smaller minicenters as well as individual investigator awards, instrumentation grants and graduate students.

Progress in our understanding of the structures and processes which constitute life and how the occurrence and progression of disease can be slowed or reversed is not only dependent on the ingenuity of the individual investigator but is increasingly tied to more and more complex technological tools.

Biotechnology is not only rapidly becoming a crucial weapon in the battle against disease but is an industry in which the U.S. currently holds a competitive edge. The NSF funding proposal on biotechnology is important to our continued leadership in that field.

We would also like to comment on Congress' directive to NSF to establish a data collection and analysis capability for the purpose of assessing the research facilities needs of universities. Upgrading and updating our research facilities and equipment is important to continued scientific progress.

As you know, Representative Fuqua's bill, H.R. 2823, the University Research Facilities Revitalization Act, would require six Federal R&D agencies, including NSF, to set aside 10 percent of their R&D budgets to fund university research facilities.

The Federation recognizes the need to address the facilities problem, and congratulates Representative Fuqua for his initiative, but we are very much concerned that the set-aside provision not erode the funding for basic research at the bench.

Knowing the extent of our universities' research facilities needs is the logical first step in devising the most appropriate response to the problem. We look forward to the Foundation's first report in September 1986.

In conclusion, the Federation urges this subcommittee to continue the Federal investment in basic research at the National Science Foundation by supporting the fiscal year 1987 funding level at least equal to the President's request.

We believe NSF remains a major focus for research and science education activities that allow our Nation to maintain a strong footing in a fiercely competitive international economy and which contribute to the improved health and wellbeing of our people.

I appreciate the opportunity to testify before the subcommittee today and will be glad to answer any questions.

Mr. WALGREN. Well, thank you very much, Dr. Krauss.

We appreciate all of your statements.

Let me ask whether you have any thoughts on—as long as we are in such an awful position, I suppose we should be able to have a lot to talk about. Wishes are not necessarily reality, and I have been struck by the sort of difference between the charter responsibilities of NSF and its budget size, compared to other research efforts in the Federal Government, not the least of which would be the military/civilian balance.

But here we are with a billion and a half organization responsible for attending to the health of the $50 billion enterprise, at least in the Federal Government. I do not know how you would measure that enterprise society-wide in terms of dollars that should be allocated towards developing the full potential and the basic health of American science.

Is $1½ billion enough for the NSF? What would the real size of an agency be whose responsibility it is to do what is necessary to secure the health and, in a sense, be a roving committer of effort across a whole range of disciplines.

Is this agency size anywhere near what it ought to be?

Dr. Rosenzweig.

Dr. **Rosenzweig**. I would be glad to take a shot at that.

If one looks at the charter of the Foundation—certainly its original charter—without a knowledge of its history, you would think you were looking at the chosen instrument of the Federal Government for the support of science and for the making of science policy for the National Government.

Now, it is clear that the Foundation has never taken either of those responsibilities fully or to a very large fraction of the totality, and there are lots of reasons for that. One of them is that that's just not the way we want to organize ourselves for the support of an enterprise as diverse and in some respects as sensitive as scientific research and education and all of the ramifications of those two.

I think one way to answer your question is that if the Foundation were to be of the size that your question posits, it would be enormous, simply enormous; I mean by an order of 50 maybe of what it is now, but that is beyond the realm of fantasy. Nobody would even want that, even if we could have it.

The question is whether, the more realistic question, I suppose, is whether it is large enough to do the responsibilities which it now has and which it seems to be growing into. And those are primarily the major responsibilities for the support of university-based basic research—that has been the core of the Foundation's responsibilities—science education at all levels from elementary and secondary through graduate, at least for important aspects of science education, and increasingly for making the links between basic science and advanced technology.

I think it is the latter that probably contains the largest prospects for growth of budget. If one were to look at the total range of Foundation activities and say, where is it doing the least compared to what it might be doing, it is probably in that area. But I think it is growing into that, assuming that this budget is approved and what seems logically to follow from it—actually follows.

Mr. **Walgren**. If I could ask you to consider another factor.

Isn't that latter element that you mentioned occupying a substantial range of the NSF budget? I am trying to think—we have education, $87 million, and I am sure we have pure basic university support—well, perhaps it doesn't. I don't know how you would estimate that.

What range would that latter factor you cite, what percentage of the NSF budget would go into that now?

Dr. **Rosenzweig**. I am really reluctant to give you a specific percentage, because I am not sure my own knowledge is sufficient to do that.

If we ask, can the Foundation spend usefully, let's say twice as much money on basic research as it is now spending, and by usefully, I mean get good science and productive science, as a result, the answer to that is, "Yes," I don't think there is any question about that. The answer to that is, "Yes," and it can do it without interfering with, or duplicating, or overlapping the research missions of other agencies.

But that is a different question than the one you asked, I think.

Mr. **Walgren**. Let me give the others an opportunity.

Dr. **Hamburg**. I'd like to take a crack at that, too. I think it is a very fundamental and refreshing question that has long-term significance.

I have, for a long time, thought the NSF was way too small for the charter functions that it had. In the area you are asking, it does not make sense to have one national agency that is broadly concerned and vigorously able to do something about the whole range of science and technology. That is pretty much what the charter says, and to what extent do we really see that that happens.

We have very heavily invested elsewhere, and understandly so, in major applications we were concerned about: One on the military side and one on the health side. Those are the two big ones.

Now, both of those have, to some degree, said we want to develop the basic underpinning for these applications. Certainly the history of NIH very strongly shows that, but even to a surprising degree the military, for example, in the Office of Naval Research, has historically said we have got to contribute something to the basic science underpinning of these applications.

Still, it is a different mission, large though it may be and broad in its interpretation. It is a different mission than having a single national agency that would really be seriously and vigorously concerned with the potential contributions of science and technology on the entire side, every facet.

Now, I think it would be ridiculous, nobody would propose to have that as a dominant, overriding, let alone sole national agency for the purpose; that would be totally out of the question, but it certainly could fulfill that central orienting mission, the broad overview function, better than it does today, if it were a good deal larger.

I agree with Dr. Rosenzweig that you could double it in the near term, and it would function well. How far one would want to go with that, I don't know. It would have to be looked at very carefully.

I would like to say one other word about the thing you are getting at. Who looks after the whole of science and technology in the country? Who really has that responsibility?

Well, you could say one place is in the Office of Science and Technology Policy in the White House, and I must say at this moment, I would very much hope that your committee, Mr. Chairman, is talking with the President or the chief of staff person about the next appointment there, but, more importantly, not just the individual, but how that office is conceived, because there is a tendency to conceive of it as a weapons office—I am oversimplifying it, but to think that the overriding function of OSTP is to deal with the weapons questions of the Nation, I submit that as important as they are—they are important—there is so much more that that office can contribute in principle to the judicious uses of science and technology in our economy and entire society, and not just the weapons, that a broad concept of the office and a broad person of high stature to head the office is very important.

The OTA also could have a larger role. It has been moving very effectively in recent years. It could have a larger role for the Congress and the Nation in this big picture function. It is a vital function. Who looks after the whole of science and technology for the Nation?

Mr. **WALGREN**. Thank you, Dr. Hamburg.

Dr. Krauss, would you like to add anything?

Dr. **KRAUSS**. I would like to say a word, also. In the eyes of the scientists of the Nation, the National Science Foundation is the keeper of the flames, so to speak, for science. It has the basic mission for basic research.

I had the privilege of working with Dr. Allen Waterman and also Vannevar Bush during the early years of the National Science Foundation, and since that time the agency has grown, and I am sure that the mission description may have changed a bit.

But in the eyes of the Nation at large, I think the National Science Foundation has a unique position of supporting that bit of human ingenuity that also leads to fundamental discoveries which we know, in the long run, lead to all types of practical applications.

Whether the NSF could be twice as big, or three times as big, productively or not, is a very complex question to answer. Suffice to say, that it is absolutely crucial that NSF be strong and that basic science know that it is supported by this Nation in order that the research scientist will recognize that he has a crucial role to play in the future of this society.

So, anything you can do to strengthen the National Science Foundation will certainly be well received by the scientists of the Nation, and I think that the rewards, that the return of investment, as we have shown so many times, will be very, very much worth the cost.

At this particular time of budgetary reduction, it is extremely important to recognize that we cannot damage the very root of our excellence and our superiority and technology and science in this world.

Mr. **WALGREN**. Are there any feelings that mission-oriented basic research has developed faster, or larger, or at an inappropriate rate compared to the development of NSF's role in filling in the gaps that might appear when one agency like the military, or one agency like NIH pushes hard on a certain area because of their narrower focus.

I guess I am still exploring for whether or not our science policy has sort of left this function of NSF either not developed as it should have developed for the most optimal of circumstances, or even declined in its presence as vis-a-vis the other kinds of narrowly directed, strong pushes in dollars and incentives in finite areas.

Dr. Hamburg.

Dr. **HAMBURG**. I think it is very important that you raised that and that the committee monitored that issue in a steady ongoing way. There is a kind of seductive quality to the lure of applications, virtually profitable applications, applications that address human suffering, applications that strengthen the national defense, and there is always a risk of kind of killing the goose that laid the golden egg—quite inadvertently. There is so much attention to sucking up the applications that basic underpinning erodes.

However, at the moment, I think the situation is, I believe, in pretty good shape, partly because agencies like the NIH are keenly aware of the intimate connection between basic and applied research that has been built in over several decades in many of the application-oriented, mission-oriented agencies.

Also, there is a factor in the conduct of science and technological innovation that has changed a lot in a way that I think, on the whole, is favorable; namely, that basic and applied are not so separate. The time lag is a lot less than it used to be. Today's basic idea may have at least a plausible, say, commercial application on a time scale of months or certainly of a few years as contrasted with the earlier time, when you would think in terms of decades.

Occasionally, I could give you examples of a century, but it's a much faster process, and the intimate interplay between basic and applied today is, I think, clearer and more vivid than it used to be, and that helps the mission-oriented agencies not to lose sight of the importance of basic research.

So, on the whole, I think we are doing OK, but it still is something that can always slip away from us and ought to be monitored, as you are doing on an ongoing basis from year to year.

Mr. Walgren. Well, I would just, from my own perspective, underline the apprehension that at least educationally we are slipping, and certainly NSF is moving in the right direction and trying to do everything they can, and the frustration is that the base with which we are working seems to be so small that you wonder whether it is enough to compete with other societies that have much greater abilities to discipline themselves and direct their energies in longer timeframes than we do.

That is particularly true in science education and that area, so, well, let me recognize my colleague, Mr. Boehlert.

Mr. Boehlert. Thank you, Mr. Chairman.

Dr. Rosenzweig, because I agree with your enlightening analysis of the tax reform bill and the negative impact on higher education, I voted against it. I just want you to know that.

Dr. Rosenzweig. You are one of the few people, Mr. Boehlert, who has called me enlightening recently. I appreciate that.

Mr. Boehlert. Dr. Hamburg, I also must confess, but I am reluctant to do so, that I voted for Gramm-Rudman, and I would point out to you that the only thing Gramm-Rudman forces us to cut is the deficit. It does not force us to cut the heart out of NSF or anything else unless we lack the real encouraging guts to stand up and say, this is important for America, and here is how I am going to pay the bill.

Mark me down in your little notebook as someone willing to raise revenue to pay for the programs we need.

Let me ask all three of the panelists to outline briefly, if you will for us, what you are doing to expand the network across America of your colleagues who will be in support of the positions you so well articulate today.

The problem is this: It is like preaching to the faithful. We are believers. We are on the same side. I was excited to see the President's approach to NSF. I welcome the 8.4-percent increase in these difficult times, and I think this committee will be very receptive to that.

The problem is, when we go from this committee to the floor of the House of Representatives, and when we talk to our colleagues, and we say NSF is important to the future of America and our international competitive position in the 21st century, a number of our colleagues say: What's NSF?

What are you doing across America to convince some guy from Nebraska who might serve on the Armed Services Committee, or someone from New Mexico on the Appropriations Committee, that what we are doing here is extremely important for this Nation now and in our future? That work is extremely critical.

Dr. Hamburg.

Dr. HAMBURG. That is something with which the AAAS has been extremely concerned. We should be, being this kind of umbrella organization. We have greatly accelerated that kind of activity in recent years, and we ought to do more. We would welcome suggestions.

Let me mention a few things. One is the R&D colloquium, now, I think, in its 11th year. It has steadily built into something that really reflects an ongoing year-round process of analyzing science budgets and what is behind the numbers, what they mean, and getting the word out through the country in a way that I think makes it a unique function.

Seeing the success there, as we have learned how to do it better, we have now started another one modeled on that, and this one is science education. We had our first one a couple of months ago, and it is going to be an annual event which brings together science teachers and school administrators and scientists and Members of Congress and the media, to get national attention to what are the frontiers to science education and how can we really make a major transformation there.

A third kind of activity for us is the congressional briefings. We have intensified that in the past few years in the area of avoiding nuclear war. We have found so much interest in these international security questions that we feel encouraged to experiment with congressional briefings, bring in people from the scientific community to present and to exchange with Members of Congress in both Houses and in both parties on science policy and science education questions.

We are just expanding that.

Mr. BOEHLERT. Dr. Hamburg, if I may interrupt you at this point.

When you have these briefings, you usually have an attendance of those of us who are already believers who are on the committee, who have a day-to-day responsibility. What I am suggesting to you is that you do not have to convince me that there is merit in what you have to say. You have got to convince all those others who are not here. There are two of us here.

Dr. HAMBURG. There has been a two-part format for those which we find encouraging, and one part is exactly as you say. There is a breakfast with Members, mostly believers, let's say, though I do notice that sometimes you and friends of yours will bring in somebody who is at the margin, and that is encouraging, and our observation is that when it comes to those staff occasions, we do have a wider spectrum of staff members who are at least curious as to what this stuff is about, and that may be a process of broadening our contacts.

We would welcome your further suggestions. It is something the AAAS especially ought to take responsibility for accelerating our activities along that line.

Mr. **Boehlert**. Here is the way you do it, and I have a suggestion.

Dr. **Hamburg**. OK.

Mr. **Boehlert**. Tell your members when we have a recess in Congress, and we all go back home to listen to our people—that's what we should do; listen rather than talk to them—you get them back home. You arrange for those meetings, because that is who Members of Congress are most responsive to, the people they represent.

Dr. Rosenzweig.

Dr. **Krauss**. Mr. Boehlert, may I make a——

Mr. **Boehlert**. Sure, Dr. Krauss.

Dr. **Krauss**. I think you should be somewhat encouraged by the activities that FASEB has in this area. We have a network throughout the country on every particular issue of importance to science and to scientists.

We communicate with that network. Many of the people in that network are not only personal friends but close acquaintances of other Members of Congress, other than those on this committee, and we make a very strong appeal that the views of science be made known to the Congress at large, not just to our friends on the subcommittee.

We have a very effective newsletter that goes out to probably about 30,000 around the country, and every issue that you address here, this committee takes into debate, is quickly exposed to our membership with urgings to go to their Congressmen and Senators and make sure that the point is made that science must be termed well if the Nation is to survive.

So, you should be encouraged that we do have a network.

Mr. **Boehlert**. That is good.

Dr. Rosenzweig.

Dr. **Rosenzweig**. Ideally, that is so with regard to university presidents. That is a small contingency, but its asset, I think, is that they are individually—and it is a group of respected individuals in their local communities, and, therefore, they have access to Members of Congress and other policymakers. When they call, they tend to get their calls returned. When they visit, they tend to get an appointment.

You will be seeing more of them—you and your colleagues—in the next several months. At least I hope you will, and we are bending all of our efforts to make sure that the number who ordinarily come to Washington, or make an effort to make their views known to their Members, tends to be a rather small faction of the total. It is significantly enlarged this year.

Now, they are not all going to come here to talk about the National Science Foundation budget. As I indicated, there is a range of issues on which they feel quite threatened, some differentially, depending upon their circumstances.

The tax bill, for example, is n[illegible] single issue for them or for us. There are four or five major provisions of that bill that would adversely affect universities and colleges, and I could cite others that are on the agenda, also. But I think the message will be to Members of Congress, there are important assets out here for which you bear a share of the responsibility. And here are the specific ways in which you can help to assure the strength of those national assets, and we hope we can be more effective in doing that this year than we have been in the past.

Mr. **Boehlert**. One suggestion, for what it is worth. Use your trustees; they are usually heavy hitters.

Dr. **Rosenzweig**. We have thought of that——

Mr. **Boehlert**. I must say, the engineers——

Dr. **Rosenzweig** [continuing]. Particularly with tax legislation.

Mr. **Boehlert** [continuing]. The engineers are doing an outstanding job. It is hard for me these days to turn around without finding another professional engineering organization who want to sit down and talk.

Dr. **Rosenzweig**. They are doing a good job; that's true.

Mr. **Boehlert**. Let me ask Dr. Krauss, if I may: Last year, the Senate made a recommendation that dealt with an area of biomedical research, NSF getting more involved in AIDS research, feeling that it is a problem of significant proportions and we should be doing more rather than less, and maybe in some areas NIH was not filling the bill.

What is your position on that recommendation from the Senate?

Dr. **Krauss**. Well, certainly there is a role for NSF-supported research scientists to play in the AIDS problem. The solution to so many of our disease problems rests in the fundamental understanding of the structure of the biological organism and the structure of those agents which are destructing that organism.

NSF has a long list of researchers who are aiming at the very key to the way in which life maintains itself and are looking at those keys which can be turned that will allow science, itself, to manipulate biological organisms, whether they be destructive organisms, as they are in the retrovirus situation with AIDS, whether they are cells that resist those destructive organisms.

So, NSF has a very real role to play in AIDS research and every fundamental research problem that faces medical science. Those at the National Science Foundation and those at NIH, both are working toward the same end, I believe, and it is always very difficult to see where the discovery will be made that ultimately solves the problem.

NSF has a superb record of discoveries which have aided medicine, and NIH has a superb record in its medical research of discoveries which have aided our basic understanding of life.

I guess, in response to your question, I think both NSF and NIH have a role to play in AIDS research.

Mr. **Boehlert**. Do you think the Federal Government is being sufficiently responsive, given the magnitude of the problem, to the overall question of AIDS? I am talking about research.

Dr. **Krauss**. My personal opinion to that—I believe that AIDS research, as part of the general complex problem of life and its sustenance, is being addressed very effectively in a number of different quarters, not only at NIH, but at NSF.

Of course, we could use additional support. And no one is suggesting that AIDS is not a crucial problem. But I think sequestering AIDS as a special case out of the whole spectrum of problems that we deal with, with viruses and their nature, is a very serious mistake. It is part of the matrix of scientific research on viruses, and I would hope that my comments do not indicate that AIDS should not be supported; but sequestering that research specifically for AIDS only is likely, especially if that drains away energies from other areas, is likely to slow down the advance to the solution rather than to enhance it.

Mr. **Boehlert**. Do you feel areas of sequestering effort underway?

Dr. **Krauss**. There always tends to be a disease-of-the-month club, if I may use the word. These are well-intentioned people who are facing the agony of particular diseases. They are powerful voices and should be listened to, but sometimes there is a little lack of understanding of the kind of science that has to go first in order for the solutions to some of those diseases to be achieved, and I am not an expert in the area of AIDS. I would be very reluctant to say whether we are doing too much sequestering or not enough. But I would predict the solution to the AIDS problem is going to come out of some very basic discoveries that could occur at NSF or NIH, either one.

Trying to sequester it into just AIDS research——

Mr. **Boehlert**. As a result of basic research——

Dr. **Krauss** [continuing]. Is dangerous.

Mr. **Boehlert**. Do you feel that something will probably eventually develop as a result of basic research at NIH and NSF?

Dr. **Krauss**. I believe so; yes.

Mr. **Boehlert**. Which leads me to Dr. Hamburg. You were very eloquent, and this is a day of eloquence, in support of the Research Facilities Act, 2823, which I am a cosponsor of.

Parenthetically, before I get to the question, let me point out to Dr. Rosenzweig, the people at Cornell who are very effective in their lobbying had me in one of their paneled dining rooms one day, and they had worked long and hard on this presentation, and I sat down and then they gave me the full pitch on how important this legislation was, and is, and I agreed with them, and I pointed out to them that I was a cosponsor. They did not have to talk to me; they should talk to some other people.

But getting back to you, Dr. Hamburg, in view of what Dr. Krauss has just said, that he feels that in so many areas, not just with respect to AIDS, but we really cannot predict to any degree of certainty where the solution to the problem will come from, but basic research is so critical.

How do you respond to those who say, in view of the tight budgetary situation, if we go with the Research Facilities Act, and once again where I am coming from—I am a cosponsor—we will, in the process, deny critical dollars for basic research; that we cannot have both. Of course, I happen to believe and I am willing, as I said, to have both and I will pay for them.

But how do you respond to that criticism of it? Now is not the time under Gramm-Rudman-Hollings?

Dr. HAMBURG. It is a constant balancing and rebalancing act, it seems to me. I do believe that the facilities, strengthening the facilities, would benefit basic research. Basic research, more and more, has become big science, whether we want it that way or not. It is inherent in the nature of the process now, so that I see the strengthening of the facilities as a very important thing for basic science and across-the-board fundamental underpinning for the progress of science in the future.

Now, as to what dollars to attach, you know, that's the kind of thing I think is a very hard judgment in terms of what is going on in a given year and what the impact would be on other programs—a very tough call.

If I may, as a quick aside, go back on the AIDS matter, since my own background is originally medicine. I have to say that it was my own view that the scientific community was a little slow on the uptake in the AIDS matter. I expressed that concern to the Institute of Medicine and elsewhere.

The Institute of Medicine then had its annual meeting last October on AIDS. The whole meeting was devoted to what is going on in the various fields, in epidemiology, in immunology, in behavioral sciences, and so on—it is very complex, including the ethical issues involved in AIDS. I think we all came away enormously reassured that after a slow start, and that, I think is true. I would exempt the Federal scene from that—I think the Center for Disease Control deserves a lot of credit; I think they saw the significance of the problem before the rest of us did, but, in any event, there has been a takeoff, and one of the features of the scientific work reported at that meeting was the extraordinary interplay between basic and applied.

I mean, the applied people with epidemiological information, were going to the basic laboratories and stimulating work in immunology, and so on. So, once it got going, it is going, I think, very well, and I doubt if momentum will be lost on that now.

It does raise a question for us to worry about: how can we have a little better sort of little warning system when new problems come along and respond somewhat more quickly?

Mr. BOEHLERT. Here is a clear-cut example, I think, of where the much-maligned and often criticized media performed a very valuable public service, because I think it took, well——

One further one, if I may. NSF supplies the bulk of Federal funding for science and engineering education, and yet the 1987 budget science and engineering request is considerably less than the average increase for NSF or the increases proposed for the other directorates.

Do you feel that science and engineering education can manage a greater increase, and, if so, what level of funding would you recommend?

Dr. HAMBURG. Oh, I do. I think that is the one part of the NSF budget with which I have to say that I am profoundly dissatisfied. I do, as it happens, sit on the advisory committee for the Science Education Directorate, so I am reasonably familiar with it. Moreover, the Carnegie Corporation of New York is heavily concerned with science education, so I speak with at least a moderate level of confidence. I think that 2 percent is really way below the national need.

Now, you can argue plausibly that the most rational way to proceed is to see what the study shows. The study has taken an awful long time to get going, and it is still about 18 months away, so to go along at this level until the study is done would lay out the strategy for NSF on the longer term in education. However, the National Science Board report of a few years ago attached very much bigger numbers and laid out clearly why those numbers were called for. It was a beautiful report, and the National Science Board's own continuing activities have attached much bigger numbers, as I understand, both in the precollegiate and in the undergraduate.

So, at the most conservative kind of level, most conservative, you know, to say that it should be 20 percent instead of 2 percent could be easily defended. The Science Board has gone a lot higher than that and with justification.

Dr. Rosenzweig. I share that, too, Mr Boehlert, and I would like to add a word, if I may, on the question of facilities because that is an issue that is likely to be lost again this year.

There is no expenditure that is more deferrable in public life than an expenditure on the renovation or construction of facilities—deferrable in preference to other seemingly more urgent needs.

The cities of this Nation, both in their public facilities and in their housing stocks, are both evidence of that proposition and eloquent testimony to the consequences of policy that is based on that proposition.

I do not think the question ought to be phrased in terms of expenditures for research, as opposed to expenditures for facilities.

The question is: What are the total needs of research in this country, and how can available resources be allocated to assure the optimum, that is, the highest quality of research of which we are capable.

Mr. Boehlert. But the reality of it is, that is the way it is shaking down, one or the other, not both. I would agree with you that we need both. I am sure the chairman would echo those sentiments.

I am concerned about the direction in which we are proceeding.

The chairman is anxious to get back.

Mr. Walgren. Thank you, Mr. Boehlert.

I just wanted to touch on a couple of other points. I will follow up a little bit on areas which Mr. Boehlert had opened up.

We talk about science and engineering education, and we see the NSF pouring substantial emphasis into precollege. In pursuit of science literacy and also some of the skill adaptability qualities in the workforce that comes with some initial science training and some science appreciation, what role should NSF have in the 2-year and the community college system?

As I understand it, the 2-year colleges are really the first post-high school years of education for literally half the people that go on and get a 4-year degree in education. Obviously, they are very close to the technician training area and the abilities of local communities to try to have an adaptable workforce.

As you know, I am interested in technician training, and I am interested in the NSF contributing something in this area.

Would any of your like to comment?

Dr. HAMBURG. I would be happy that you raise it. It is very crucial. One reason is the relation to technician training and the necessity of a broadly skilled workforce.

Another is that there is such a high concentration of minorities in those institutions. Now, in addition to equity considerations about how we can overcome the historic obstacles of getting minority participation in science-based careers, all the way from technicians to science-based professions, to basic scientists, but in equity considerations there is a very practical national interest consideration, and that is the cohort of young people coming along over the next few decades is very likely to be a substantially smaller cohort of young people than we have had, and within that cohort a larger proportion will be minorities than we have had before.

So, the size of the cohort may be affected by immigration; even so, the problem will be very similar. If you have a lot of immigration, you are going to have a lot of young people who are going to be, on the whole, lacking in an optimal preparation for science-based careers.

So, we are faced with the situation that those community colleges and 2 year schools are going to have a high density, as it were, of people who have not been in the mainstream of preparation for science-based careers and who are more badly needed by the Nation for a skilled workforce or technical society than has ever been the case.

There is a kind of a vacuum there. In turn, if you ask, who is going to help those institutions do what needs doing in modern science, I think there is a kind of a vacuum at the moment, and I do believe that there is a leadership function to be played by NSF there, obviously working in the most cooperative way with the States and localities.

Mr. WALGREN. Let me ask, also—you indicated, Dr. Rosenzweig, I think in your testimony, that the behavioral and the social sciences have come back a little bit over these years, are back to the 1980 levels, or thereabouts. I guess the question is: If we bring a science education and research support function back to 1980 levels in 1987, shouldn't we really be worried about that area of discipline, and whether or not there is some way that we could encourage, perhaps through some of the cross-directorate support, some added strength to the behavioral and social sciences.

My instinct is that they are vulnerable to being left out of some of the cross-directorate efforts because the cross-directorate effort, which seems to be the way we are going in NSF as the disciplines merge and the like, tends to be more mission-oriented, perhaps, than the social sciences and perhaps less so the behavioral sciences would find applicability in.

Is there some creative suggestion we can make for the behavioral sciences and the social sciences, or are we simply left to wrestle this number in terms of percentages year by year?

Dr. Rosenzweig. My sense is that it is probably the latter. It is, I suppose, a sad comment to be talking favorably about a budget line that has managed to get itself back in 1987 to the level of 1980, but that is where we are, and I suppose we have to be grateful for at least that.

My sense of the behavioral and social science programs at the Foundation is that the major data base programs in economics and political science, particularly, are in reasonably good shape now.

What is lacking is funding for accessing use of those data bases plus other lines of research that take the form of investigator-initiated research projects. There just is not much money for that.

Now, I think that it is perfectly rational and sensible to use whatever resources are necessary out of the total to sustain the data bases, because that is the future of very important areas of social science research in this country, but it is also, at least in the short run, I think, short-sighted to fail to take advantage of their availability, plus the availability of other lines of productive research by starving the investigator-initiated research lines.

I don't know that there is any answer to that that's internal to the Foundation. I think it is a question of more money.

Mr. Walgren. Sort of like holding the cost of high energy physics facilities against the investigator research support that would be necessary to have action in that area.

Dr. Rosenzweig. That's exactly right, Mr. Walgren.

Mr. Walgren. Dr. Hamburg.

Dr. Hamburg. I do think it is a creative suggestion that you make, and I have one concrete response to it, that is, about cross-directorate initiatives.

The engineering research centers, which are getting a good deal of upper attention, there we might take a leaf out of the book of the National Academy of Engineering, which, as Robert White, the president of the academy, testified before this committee, I believe, last year, has initiated a program at the academy on technology and society, and what he is trying to do is bring together engineers and social scientists to look at certain basic issues, major technological thrusts where: what can we foresee about technological changes in the time scale of a decade or so; what will those technological thrusts probably mean for the economy; what, in turn, is likely to be the educational implications of those economic changes; what kind of workforce will you need; what kind of social adjustments will need to be made to deal with the new technologies and the consequent economic changes.

That is a very important set of issues, and I see no reason why the engineering centers shouldn't be fostering research that would make that conjunction of engineering and social sciences that the Academy of Engineering is trying to make.

Mr. Walgren. Thank you, Dr. Hamburg.

Along this line of the thought that there are areas that are not receiving what they might. Are you folks concerned about the balance of individual investigator research and the investments in centers and other kinds of programs by NSF? It is our understanding that individual investigators now occupy about 66 percent of the NSF budget.

All the real initiatives that seem to be coming along, and they are smaller, of course, are in areas that seem to go more to institutional innovations rather than adding individual researchers.

Is there a number here that we should be concerned with? Are we at the lower range where individual investigator support should fall in the overall budget of the NSF? Is this an area that we ought to be trying to signal that floors ought to be put under it so it does not fall further?

Dr. **Rosenzweig**. It is hard to specify a number that is right and a number below which you are at danger. My sense is that there one ought to raise a warning signal about significant absolute reductions in investigator-initiated projects.

I am not sure that the figure to focus on is the ratio of those to the total budget.

I think there are two kinds of judgments that have been made in the last few years in the Foundation budget and perhaps elsewhere, also. One is a substantive judgment that there is important work that can be done best through cross-disciplinary centers of some kind, which establish an institutional framework, bringing people together on problems that are best approached from different directions. That's a substantive judgment.

There has also been a political judgment that that's the best way to attract attention to topics that have great political appeal and, therefore, are more likely to be supported in the Congress than simply an increase in unspecified investigator-initiated research.

I think that both of those judgments have to be taken seriously. I don't denigrate either one of them. I think it is terribly important for this committee to be asking the kinds of questions you have asked, not necessarily of this panel, but of the managers of the Foundation as well.

Mr. **Walgren**. Let me turn to Dr. Krauss, and then I want to address a specific question to Dr. Hamburg.

Yes, Dr. Krauss.

Dr. **Krauss**. I would like to second what Dr. Rosenzweig has just said. There is certainly a place for centers and institutional organizations to do specific kinds of research, but I think at this particular juncture the individual investigator feels somewhat threatened by perceived erosion of funds flowing to the investigator-initiated grant mechanism.

Even when centers are formed, focusing attention on a given problem or allowing for interdisciplinary action, in the last analysis the people who go to those centers stay in those centers, survive in those centers, on their ability to attract investigator-initiated research funds through the normal grant sequence.

So, there is somewhat the specter of administrative subsets being developed all over the place, but ultimately that has to be borne by the individual investigator. So I think that while I don't want to say there should not be centers, I think the Congress should be very cautious in doing good things in this area that do not erode the wellspring of ingenuity that ultimately is going to support the centers, themselves, and that is the individual investigator research grant.

Mr. **Walgren**. I understand, Dr. Hamburg, that the AAAS has been interested in this area, and that there is some exploration being made of it. Can you fill us in on that? We certainly want to encourage any evaluation of it that might be done.

Dr. **HAMBURG**. It is at an early stage in our thinking, Mr. Chairman, but I hope that it could be something helpful.

The problem has been coming up from different sectors of the scientific community, and that is why it kind of passed the threshold of the AAAS.

The centers are very diverse. That is one point to make. They are all under that rubric, every conceivable kind of mixture of enterprises, and one needs to sort out what are the different kinds of centers.

There are multiple aims. One is to get people from different perspectives together to work on an important problem. Another is to provide a setting where the intimate connection of basic and applied research that I was alluding to earlier can conveniently be made.

Another, and very important one, is to provide an opportunity for young scientists emerging, even tentative scientists to get a start in a stimulating and protective environment.

There are questions being raised: Where do young and emerging scientists begin these days? What conditions foster getting not only the technical skill, but getting over some of the discouragements that seem to be on the horizon for young people with respect to science-based careers.

That has come up not only with NSF, but NIH, the Alcohol, Mental Health and Drug Abuse Administration. A variety of places are in the mood to have another look at centers, and so the AAAS felt it might be helpful to at least make a preliminary assessment that would kind of look broadly at the experience of different institutions. And we would want to do it, I would say, not only in cooperation with the major funding agencies, like NSF and NIH, but also—this will be a surprise to Dr. Rosenzweig—we would like to do it in a close working relationship with AAU, because we would want to focus it, at least sample it, at some of the major universities, and see what it would look like from the university's point of view as well as the funding agency's point of view.

Maybe there ought to be a two-stage process after some preliminary assessment of a perhaps some quick and dirty, but informative type and then, perhaps, come to you and discuss whether there ought to be a more definitive study.

At any rate, my point is, the AAAS would like in getting some kind of special overview of what is happening with the centers, and what we really mean by centers, and whether we can now sort out some of the conditions under which centers are really useful.

Mr. **WALGREN**. I had one other thought that struck me as important. I would like to get a quick reaction to enabling the director of the NSF to appoint his assistant directors without requiring White House approval. Helpful? Not helpful? It was a change that was proposed in the Organic Act, and we have apparently come through a period where there was some lag in appointing assistant directors. They are appointed now. This is not anything aimed at a political question. It is just simply: should the director have to wait for the White House to approve assistant directors?

Dr. **Rosenzweig**. I think not, myself. At the assistant director level, I think those ought to be treated as professional appointments and not political appointments.

Dr. **Hamburg**. I agree.

Dr. **Krauss**. I would second it.

Mr. **Walgren**. OK.

Then, one other—I apologize for taking the time, and it is because this panel is such a good panel—Dr. Hamburg, you mentioned the singularity of the Federal role in basic research and the importance of realizing that the Federal Government is the funder of that.

The question is: In making that point, is there anything that could be said about efforts to encourage the private sector to participate in cost sharing? On the one hand, other Members of Congress, or anybody, would like the private sector to give them whatever they can give. But our point is that they do not give in that area and instead say that they gave at the office, or something to that effect.

Do any of you have any arguments you would like to make about how we really are quite alone in funding basic research, or at least should feel quite alone and, therefore, willing to put the Federal dollar in there without having to prove that the private sector cannot perform that function?

Dr. **Hamburg**. I have been very much interested in this over a period of years. I certainly would like to see a greater contribution to basic research from the corporate world. But what we have seen is not that, but a different encouraging development which I allude to briefly in my testimony, that is, a big upsurge in R&D, and that is in your sense, Mr. Chairman, of giving at the office; giving at the office by heavily investing in applied research and development.

When you talk with the leaders of corporate science and technology, they tend to say that is the appropriate role. They do a certain amount of giving to the universities, and in one field, at least in recent years, in biotechnology there have been some very well publicized cases of rather major grants to the universities for support of basic research; but when you talk with the leaders in the industry concerned with those matters, they expect that if it takes off, they will more and more build in-house capability to pursue the applications as a legitimate and proper function.

They are the first to say it is not our, the corporate sector's, responsibility to do very much. We can have some stimulating function; yes, we can help, but it is fundamentally the Federal Government's responsibility to see that the basic research on the large scale is supported.

I think that is their position, and I think it is defensible.

Mr. **Walgren**. Let me ask Dr. Rosenzweig, then, if he could address these numbers.

Am I right in thinking that 50 percent of university research is paid for by the Federal Government? And that would imply that 50 percent is coming from someplace else.

Dr. **Rosenzweig**. I am not sure where that figure comes from. A good fraction of it is supplied by the institutions, themselves, of course, in the form of salaries and other infrastructure arrangements.

My recollection is that about somewhere between 5 and 6 percent of the total volume of sponsored research—that is money coming into the institutions for the sponsorship of research—now comes from industry.

I think it is quite unrealistic to expect a substantially larger fraction of the total to be borne by private industry. I mean, it is just contrary to the nature of the kind of economic system that we run in which profits are inevitably and properly a central calculation in the private sector, and it is the old story, Mr. Chairman, that the costs of basic research are borne locally; the benefits are widely dispersed, and quite unpredictable, and, therefore, it is a social good, and the cost of it has to be borne socially.

Mr. WALGREN. All right.

Well, we have been joined by Mr. Bruce, who was more successful than the rest of us in getting a supercomputer center for his domain, and I ought to recognize him in that light. Mr Bruce?

Mr. BRUCE. Thank you, Mr. Chairman.

I have no questions.

Mr. WALGREN. OK.

Well, we have gone on for a long time, and there is only one other thing I want to add, since Gramm-Rudman came up earlier, and since I, as probably most, voted for Gramm-Rudman, I just hope that all of us as citizens appreciate the degree of the hemorrhage in interest payments that was occurring, and continues to occur. The interest costs, as you know, but I think that this is sort of information that I would like to offer to other folks in the room.

Interest costs in 1985 are about $80 to $90 billion more than they were in 1980. That means that if you had just the money that has now been committed to, and sadly imbedded in, every future budget year to interest for the loans that were made, or the borrowing of the Government in the process of Reaganomics alone, you had just that amount of money instead of, well, we ought to think of the uses it could be put to instead of the use for interest costs, which, from every definition, is just waste.

It is a tax dollar taken in a future year for which nothing of value would be delivered to the taxpayers and citizens of that year. And that has been imbedded in every future year forever unless we can pay off the underlying principal, and none of us really expect to be able to do that, because, if we get to a balanced budget position, there certainly will be compelling social needs.

Mr. BOEHLERT. Mr. Chairman, would you yield?

Mr. WALGREN. Well, I would just like to state the frustration of being able to multiply the NSF budget by 80 times. Those moneys will be paid now, or the moneys were there; they will be used in every future budget. But instead of being used to do something like multiply the whole effort that we make with the NSF by 80, they will be spent on interest for which there will be nothing returned to anybody.

And so the measures justifiable to stop that kind of hemorrhage were clearly strong. And sadly, that $80 billion understates the impact, because if we walk down a slope at the same rate that we walked up the slope, after 1991, we will be paying literally something in the range of between $160 and $200 billion in interest only for the borrowing done between 1980 and 1985, essentially. And those, as I say—those costs and that waste has now been imbedded in every future budget year. It cannot be sunset as a practical matter.

So, it was clear that even though none of us would endorse the damage that will be done by Gramm-Rudman, we have to stop a far larger volume of damage that is being done by going on in the present course.

With that, Mr. Boehlert?

Mr. **Boehlert**. Just one brief comment, Mr. Chairman.

I think we all share the frustration you have expressed. Incidentally, we have been here for 2 hours, and since we have been here, we have paid out $30 million in interest on the national debt. That is a little figure you can tuck away someplace. We spend $360 million a day.

My only quarrel is with that one word Reaganomics: I want the record to show that Ronald Reagan did not invent the national debt. He did not invent deficit spending. That has been with us far too long, and I think there is enough blame to go around for everybody, but I agree with your statements, Mr. Chairman, with that one qualifier.

Mr. **Walgren**. If the gentleman would yield, and I would only ask him to yield, and he can take back the time that he wants.

I think that maybe it does help to sort of clear the air a little bit, and I would like to offer for people's consideration the fact that in all future years now, or in this present year, we are paying the interest on the national debt through 1980 with $60 billion of cost, and we are paying an additional $80 billion for the borrowing that was done since 1980.

Now, in 1979, the total budget deficit was $27 billion. It was, within 3 years after that, $212 billion. Almost all of the—if you graph Government programs between those years, you will see that almost the full increase in stress on budget deficits is attributable to the tax changes that were made in 1980 and the increases in military spending that were made in those 5 years, and although there is enough responsibility to go around, some of that responsibility is more theoretical, in my view, than it is practical. And when you view the history of the United States and realize that whenever a President sends a tax reduction bill to the Congress, the Congress essentially asks how low would you like it; and whenever a President sends a military commitment to the Congress, it is my understanding that no President in the history of the Nation has ever been denied a major military commitment that he sought to make; and if that applies to Millard Fillmore, it would apply in multiple exponential terms to Ronald Reagan, plus the television.

So, I think that when we, as citizens, judge what has happened in these years and who is really responsible for what will be several years from now a missing $200 billion in every budget year committed to waste, I hope that historically will replace responsibility where it truly lies.

Well, I apologize for that. We will go on to the next panel. [Laughter.]

Mr. **Boehlert**. You have met the enemy, and he is us, and you need to look no further than Capitol Hill to find the source of some of our most serious financial problems.

Mr. WALGREN. Well, with that outburst, let us turn to the next panel and express our appreciation for all of you being a resource to us. It is very valuable, indeed.

The next panel: Dr. Clifford Murino, who, as I said at the outset, is the president of the University Corp. for Atmospheric Research; Dr. James Baker, the president of Joint Oceanographic Institutions; Dr. Robert Hughes, president of the Associated Universities; and Dr. John Teem, president of the Association of Universities for Research in Astronomy.

Welcome, gentlemen, to our discussions, and let me just say again at the outset that written statements will be incorporated as part of the record.

It will be helpful for everyone, and particularly for those reviewing the record, if you try in your oral statements to highlight parts of your written statement, so that someone could then go back and refer to them for detail and content. In any event, being mindful of the time—I apologize for having gone longer with the first panel than we will be able to do in this instance and therefore ask you to use some restraint in your presentations.

Let's go through the panel in the order in which we called you, and we are very pleased you are here and appreciate your being part of our record.

Dr. Murino?

STATEMENTS OF DR. CLIFFORD J. MURINO, PRESIDENT, UNIVERSITY CORP. FOR ATMOSPHERIC RESEARCH; DR. D. JAMES BAKER, PRESIDENT, JOINT OCEANOGRAPHIC INSTITUTIONS, INC.; DR. ROBERT HUGHES, PRESIDENT, ASSOCIATED UNIVERSITIES, INC.; AND DR. JOHN M. TEEM, PRESIDENT, ASSOCIATION OF UNIVERSITIES FOR RESEARCH IN ASTRONOMY, INC.

Dr. MURINO. Thank you, Mr. Chairman. I do appreciate being invited to appear before your committee. My comments I will keep brief, and they will be informal rather than a prepared written statement.

I appear before you as president of the University Corp. for Atmospheric Research. UCAR is a consortium of 55 universities and includes virtually all of the universities in the United States that offer the Ph.D. in atmospheric and ocean sciences.

My testimony includes a list of the member institutions.

As you know, Mr. Chairman, UCAR manages a number of major national scientific activities, including the National Center for Atmospheric Research, National Scientific Balloon Facility, and the Computer Science Network, and UCAR carries out as well many other related programs in atmospheric research on behalf of the university community and the Nation.

Today, I am going to focus on our relationship and involvement in the management of NCAR. There are many other activities that we do undertake, and, if time permits, I will get into those, but my written testimony contains details on that.

For the past 30 years, the atmospheric sciences have made major progress in coupling theoretical advances with new technology with the use of satellites, super computers, radars, and research aircraft. And we have developed the most sophisticated atmospheric chemical sensing instrumentation which will enable us to make major progress now in the atmospheric sciences.

Science and the information we get from this research is extraordinarily important when one looks at the crucial social problems of the warming of climate due to carbon dioxide, for examples, in trace gases, or through the improved prediction of damaging severe storms, hurricanes, tornadoes, snowstorms, drought, and the like, or the hazards to aircraft safety from windshears.

This kind of research and information is crucial, I think, to societal needs. Clearly, the world needs for food, clean water, clean air, are constantly increasing, and we are increasingly dependent upon the communications, transportation, for the smooth flow of commerce and our economic wellbeing.

Atmospheric research is central to these problems, and the ability to understand man's impact on climate, or man's impact on air quality, are central to solutions to those problems.

What does it take to do high-quality research in the atmospheric sciences? First of all, the atmosphere is a vast three-dimensional domain with many complex problems. The physical processes going on, the chemical processes going on, within the atmosphere are difficult and often not yet tractable. The processes operate on space scales from microscopic to global.

Comprehending all of this requires, first of all, collaboration of science from many disciplines, many institutions, many countries, and it requires the research facilities necessary to conduct that research: computers, research aircraft, radars, and satellites. This fact was recognized some 25 years ago, when a committee of the National Academy of Sciences, and then UCAR, proposed the creation of a national center for atmospheric research.

NCAR was created some 25 years ago with three major missions: first of all, to undertake a program of research of the highest quality on the most important and challenging problems of the atmosphere and involving collaboration with scientists from the universities and other research institutions.

Second, it was to develop and make available to the university community and to the NCAR scientist the advanced and sophisticated research facilities necessary for progress on atmospheric research.

And, finally, NCAR was to be the intellectual center where the world's leading meteorologists and atmospheric scientists could gather to plan the most effective and promising attacks on these crucial problems of the atmosphere.

Today, NCAR is judged by almost everyone as being the world's leading atmospheric research center, and, I think, you ought to be proud of that fact in your role in the support of that center.

But the point I want to underscore with you today is the crucial role of the linkage of the NCAR scientific community and the university community in producing that superb atmospheric center. It is because of the close relationship of the university scientist, the individual scientist working at home, with NCAR that makes the atmospheric sciences work today. NCAR is literally at the center of the academic atmospheric sciences research effort.

Virtually every university scientist in our field plugs into NCAR in one way or other, either through the use of facilities or through the close collaborations with scientific research on these important problems

It is fascinating to note that half of the research papers published by NCAR scientists are published in collaboration with scientists from the other institutions, principally the universities.

NCAR, on the other hand, has made it possible for these individual university scientists to become involved in the major national and international programs addressed at solutions to these crucial atmospheric problems. So, if NCAR has made its major contribution, I think it has been in that it has enabled the university partners and NCAR to focus the Nation's scientific talent on these most crucial problems of the atmosphere. It has provided a framework to sustain research programs over years, or decades, that provides the facilities necessary to do the research.

That is the role of NCAR.

The role of UCAR is one of governance and management overview of the national center. It is undertaken and carried out by a tier of involvements of the university member community. First of all, there are the members' representatives, 2 from each of our 55-member institutions. They meet annually in Boulder to review the NCAR program plans and program directions.

They, just this past October, addressed an issue that you raised with the previous panel, Mr. Chairman, on the question of the balance of money going to the grants program or the individual lone scientist versus the national centers, and, in our case, it was in the atmospheric—NCAR—the National Center for Atmospheric Research, and we spent an afternoon addressing various balance issues, and it was outstanding to see the tremendous support of the university community for the right fit that we now have between the money going into NCAR and the money going into the grants program. They are comfortable with that. They believe this is their center. It is fully supportive of the work they wish to do.

The members' representatives conduct a number of important processes for us through their various committees. They elect what we call a SPEC committee, scientific program evaluation committee, which undertakes a thorough and complete evaluation of the scientific quality of each of NCAR's programs on a 3-year cycle.

It looks at the quality of the science. It looks at the quality of the planning, and it looks at the cost-effectiveness of the use of the resources that have gone into that science.

The reports of that committee and many panels of experts that work under it are presented to UCAR, they are presented to the National Science Foundation, and they are presented to the public; so, it is an open process. Everyone knows about the results of the critical evaluation of NCAR. And year after year, these evaluations have underscored the high quality of the NCAR research program.

The members' representatives elect a Board of Trustees, and it is the Board of Trustees that has the full legal and fiducial responsibility for management of the corporation. They meet quarterly, and many other of their committees meet even more regularly than that.

The board of trustees is made up of the highly prestigious, experienced management and science people from the atmospheric sciences and related sciences. They get very deeply into the NCAR program and to review of the budgets and plans for NCAR. It is the board of trustees that, in fact, does set the program directions for the national center.

This past year, the Board adopted a vision statement, a look at where NCAR ought to be 10 years from now, and what ought to be the main thrust of its science program, and that vision document is the one that is used as a backdrop against which we now judge and make determinations on the individual budget priorities year by year.

The board is deeply involved in making determinations such as what are our priorities for new initiatives in the atmospheric sciences and at NCAR, but especially—and the more difficult ones—are what ought the new priorities to be in terms of what is going on; how can we now take on new responsibilities within the current levels or even within declining levels; that is to say, how do you get new things started? What should be started? And in order to do that, what things must go?

Those are the determinations that the Board is deeply involved in and doing all the time.

There is, then, this enormous involvement in the governance of UCAR by the university scientists through the Board, through the members, through their members' committees, and this is, I think, the reason why the university community has been so supportive of NCAR. They do believe that it is their center. They are involved with UCAR; they are involved with NCAR.

We have added up for fiscal year 1985, some 3,000-person-days of consultation that were contributed free of charge by the university community in UCAR affairs and NCAR affairs.

I have given you details of Gramm-Rudman impacts and other activities of UCAR in my written testimony. I won't go into that now. I think I would just like to mention one other program that should be of interest to you, based upon your discussions with the earlier panel—perhaps two.

One is in the area of education. We are proposing and have put together a plan for UCAR's involvement in precollege education. This would involve both the UCAR, which is the university community; it would involve the American Meteorological Society and private industry.

But of special interest to you might be a program where we are working closely with American industry. It's called our Corporate Affiliates Program, and our intention there is to make sure, or to do whatever we can, to help U.S. industry be competitive.

It is a self-supporting program, and there are now some 14 corporations involved in the Corporate Affiliates Program, including IBM and General Motors, RCA, the major corporations, DEC, John Deere, Weyerhauser, the companies like that.

What we do for them—they pay a fee, but it's a nonprofit kind of operation—what we do for them is provide them with the latest information on the output and the result finding from the university community and from the NCAR scientific community on what we are learning about the atmosphere and how it affects them.

We handle—we've got the symposia and workshops; we visit them; we see how they are weather-dependent and their interest in weather and atmospheric processes and then keep them fully informed.

It is working very well. They are happy with the program, and, in fact, in recent months it looks like we are going to be having some spinoff benefits; some of the companies want to get involved in supporting some of the research effort, or at least work cooperatively with us in UCAR and the UCAR universities and at NCAR.

I think that will complete my remarks, Mr. Chairman, for now.

Thank you very much.

[The prepared statement of Dr. Murino and answers supplied to questions for the record follow:]

PREPARED STATEMENT OF DR. CLIFFORD J. MURINO

I. INTRODUCTION

Mr. Chairman and members of the Subcommittee, my name is Clifford J. Murino and I reside at 1590 Bradley Drive in Boulder, Colorado. I am here today in my capacity as President of the University Corporation for Atmospheric Research in Boulder, Colorado. As you requested, a brief biographical sketch is included as an attachment to this testimony (Attachment 1).

The University Corporation for Atmospheric Research (UCAR) is a consortium of 55 institutions of higher education in North America, and includes virtually all U.S. institutions with Ph.D. programs in the atmospheric and closely related sciences. The consortium is a private, non-profit corporation. A list of our 55 member institutions is attached to this testimony (Attachment 2).

As you know, UCAR operates the National Center for Atmospheric Research (NCAR) under the sponsorship of the National Science Foundation, and carries out a number of other activities that I shall discuss later. The steady support NSF has provided for NCAR since its founding 25 years ago has been of inestimable value in the development of NCAR, and has enabled the U.S. to stay at the forefront of atmospheric science.

The Center is, in the view of many scientists, the outstanding atmospheric research laboratory in the world. The NSF and the member universities of UCAR can take a great deal of pride in the success of NCAR and in the accomplishments NCAR shares with its scientific colleagues in U.S. universities, government laboratories, and private industry, and with cooperating scientists around the world.

My testimony will deal with the nature of NCAR's work and its contributions to the science and to the national interest, and how our Corporation has developed the Center, guides its programs, and ensures that community produces results that are of value to the country.

I will also touch on other subjects which your staff has told me are of special interest to the committee, including potential impacts of the Gramm-Rudman approach to budgets, the role NCAR plays in the provision of supercomputing services to atmospheric and oceanographic research, details of UCAR's role in setting priorities for NCAR and in working with the National Science Foundation, and the matter of indemnification of UCAR for activities at NCAR and elsewhere.

II. CONTRIBUTIONS OF ATMOSPHERIC RESEARCH TO THE WELFARE OF THE NATION

First, however, I will describe briefly why atmospheric research is important to the nation and the world, and why it merits the special attention of the Congress.

In the past thirty years, atmospheric research has come of age.

Theoretical advances have been accompanied, and in many instances have been made possible, by new technologies, including ultra-high-speed computers, radars, satellites, instrumented aircraft, and many kinds of sophisticated sensing devices. An example of the latter capability are chemical instruments that can measure trace gases in the atmosphere down to a few parts per trillion; some gases, such as fluorocarbons, can affect atmospheric quality and climate even at these low concentrations.

Especially during the past 15 years or so, using these new tools, atmospheric research has contributed important information on atmospheric problems of great concern to you and to the nation. These problems range from the warming of the climate due to carbon dioxide to the detection of tornadoes and the discovery of the cause of dangerous windshears and how to increase aircraft safety when they are present.

In these last years of the twentieth century, the world's needs for food, clean water, and breathable air are constantly increasing. At the same time we increasingly depend on communications, transportation, and the smooth flow of commerce to sustain our economic well-being. Thus the need increases to develop reliable warnings of severe weather; to anticipate major changes in climate and the subsequent impacts on food production and water supply; to understanding the impacts of human activity on climate and air quality -- such impacts as acid rain, warming of the earth caused by the burning of fossil fuels and tropical forests, and the extreme climatic damage that a nuclear war may bring.

In short, we are increasingly in need of fundamental knowledge about the atmosphere and its interaction with living things, so that we can pursue the twin goals of economic prosperity and sound environmental policies with equal effectiveness, and so that we can avoid doing inadvertent and possibly irreversable harm to the only atmosphere we have.

To the production of this essential store of information, the atmospheric research community is dedicated. Well-trained scientific manpower is available and is increasing, thanks to the effective educational efforts of our universities. The technological tools are available or within easy reach. The production of useful knowledge is accelerating. Given adequate resources, the atmospheric sciences are poised for rapid progress in the next few decades.

III. THE ROAD TO PROGESS IN ATMOSPHERIC RESEARCH

The atmosphere is a vast, three-dimensional domain in which many physical and chemical processes are simultaneously at work. These processes take place on many space scales, ranging from the microscopic to the global, and the processes interact with each other in great profusion and in bewilderingly complex ways.

Comprehending how an individual process works -- for example, the formation of raindrops -- is difficult in itself. Putting together all of the forces that lead to a severe hailstorm or a rash of tornadoes in such a way that the total system is understood and can be predicted -- that is a far more difficult task, requiring the dedication of many scientists, their students and their technical helpers, often for a period of many years, and using arrays of expensive and complex research tools that a single university cannot normally obtain on its own.

This collaborative approach is essential to successful exploration of nearly every important issue in atmospheric research, from air quality to climate change to improved weather prediction. This was clearly foreseen during the late 1950's, when a committee of the National Academy of Sciences and that of the University Committee on Atmospheric Research (UCAR) called for the establishment of a national center for atmospheric research. Only through such an institution could the atmospheric research community combine to develop essential knowledge of the critical problems of the atmosphere. In 1960, the National Science Foundation undertook to sponsor such an institution, which was to be operated by a corporation of universities, UCAR. The NCAR success story is the result.

IV. THE NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

NCAR, which has its headquarters in Boulder, Colorado, has several interrelated missions.

The first is to identify, plan and carry out, in collaboration with scientists of the national and international communities, research projects on problems of national and international scope and importance. The importance is measured not only in scientific terms but also in the ultimate potential for useful application of the knowledge produced.

The second is to identify, develop and provide to the atmospheric sciences community advanced research facilities required to make progress on these important atmospheric problems.

Finally, NCAR is a planning center where the world's leading atmospheric scientists gather to determine the most promising strategies for attacking the large problems of the atmospheric sciences.

The research conducted at NCAR, in collaboration with the community, is in the following areas: The dynamics of weather and climate; the study of the clouds and cloud complexes that produce most of our severe weather as well as much of our beneficial rain and snow; the chemistry of the atmosphere on global and regional scales, including such man-induced phenomena as acid rain; and the interactions among the atmosphere, the oceans, plant and animal life, and the sun.

Current facilities include specially instrumented aircraft; field observing tools such as radars and automated recording systems; special vehicles such as high-altitude, long-lived balloons; special data handling and communications systems; and computers of the highest speed and capacity.

It cannot be repeated too often that the success of NCAR has depended upon its close relationships with universities. More than half the scientific papers NCAR produces are written in collaboration with scientists from other institutions. NCAR has active visitor and postdoctoral fellowship programs; many graduate students do all or part of their thesis work for their home institution while visiting NCAR; summer workshops and colloquia bring leading scientists and students together to identify promising research paths for future work.

NCAR has made possible the involvement of university scientists in many national and international scientific enterprises. These include many aspects of the Global Atmospheric Research Program, which led the way toward great improvement in weather prediction ability and in our understanding of climate; the National Hail Research Experiment and the Cooperative Convective Precipitation Experiment, which produced much knowledge of the formation and behavior of the convective processes that produce hail, heavy rains, flash floods and high winds; experiments in the processes that produce acid rain; satellite experiments dealing with the behavior of the sun and the earth's upper atmosphere, and many other such research programs. At this moment, university and NCAR scientists, aircraft, radars and other facilities are engaged in an experiment off the coast of North Carolina to help improve the prediction of the storms that form in that region and bring rain and snowstorms to the middle Atlantic states, including the city of Washington.

I have yet to describe, however, what I regard as the greatest benefit of NCAR. Thanks to the collabaration of scientists from NCAR and universities and to the array of research tools NCAR has developed, the atmospheric research community has sharpened its view of what is truly important in atmospheric research and has focused the bulk of its efforts upon those important problems.

What has therefore been achieved through the work of NCAR and its partners is to focus the nation's scientific talent on the most critical problems of the atmosphere, to provide an institutional framework necessary to sustain research programs over a period of years or decades, and to provide the facilities necessary to do the work. That is, in my view, NCAR's unique contribution to science and to the nation.

While I cannot, in this testimony, list all the research accomplishments of NCAR, the following examples will characterize them:

- First measurements in the stratosphere that confirmed that fluorocarbons are depleting the earth's protective ozone shield.

- Development of Doppler radar techniques that can detect severe windshear in the vicinity of airports and provide timely warnings to aircraft attempting to take off or land.

- First systematic measurements of atmospheric hydrogen peroxide, the compound believed to modulate the amount of acidic rain that will fall from clouds.

- Establishment that an array of trace gases, including fluorocarbons, methane, ozone, and various nitrogen compounds, produce as much of a greenhouse effect as carbon dioxide, and thus the likelihood that a significant increase in the temperature of the earth's atmosphere will occur in the next half-century.

- Significant contributions to techniques to use Doppler radar to identify areas of probable tornado formation.

- Research indicating that there are true connections between the so-called "El Nino" (an unusually warm pool of water in the equatorial Pacific Ocean) and subsequent unusual climate events elsewhere around the globe.

- The generation of a sophisticated and realistic model of climate that is now being used by more than 25 climate research groups around the country.

- Discoveries that have shown that the sun, once thought to be constant in its output, can vary greatly on time-scales of minutes to centuries.

- Development of the most versatile and capable Doppler radar now in use.

- Development of a system whereby hundreds of scientists at more than 100 remote sites can use the NCAR CRAY computers from their home institutions.

In summary, there exists a synergism that derives from the intimate linkage between NCAR and the universities. On the one hand, a major reason for the extraordinary quality of the NCAR research program is in the infusion of ideas and people into NCAR from the university community. On the other hand, the universities and ultimately the nation benefit by having the university research programs focused on and involved in the critically important atmospheric problems through NCAR. This synergism exists in large measure because the universities through UCAR have a central role in the governance of NCAR; that is, they have a direct, effective, and codified way of influencing program directions and priorities, and the quality of work, at NCAR. Because of UCAR, and its role, the university scientists have a pride of ownership of NCAR--this is their center. I will describe UCAR's role in the management of NCAR next.

V. UCAR'S GOVERNANCE OF NCAR

In this section, I will describe what I believe to be the most important job of UCAR, the organizations and function of the Corporation, and the way the Corporation sets priorities for the National Center.

UCAR's most important job is to help make the right things happen in atmospheric research. As I have indicated earlier, the path to the full effectiveness of atmospheric research is through (a) identifying the most important problems to attack, (b) planning and organizing research efforts that require the collaboration of scientists from many institutions over a period of years, (c) developing and providing the special facilities needed for such efforts, and (d) making sure that the results are packaged in ways that are useful for further research and for application by policy makers, the public and the private sector.

To make these things happen is UCAR's goal. A consortium of 55 member universities, its special role is to foster the health of the university atmospheric science community and, more importantly, to involve the university community in focusing its efforts on that set of atmospheric problems that will most effectively advance the science and serve the public interest.

In addition to planning and managing NCAR and fostering collaborative work among NCAR and university scientists, UCAR conducts other activities to advance the science and benefit the community and the nation. These include managing the National Scientific Balloon Facility and the Computer Science Network, special efforts in education, research and technology development, training, joint projects with the private sector, technology transfer, and multidisciplinary research. These are described further in the section below entitled, "Other Activities of UCAR."

The Roles and Value of UCAR.

UCAR's effectiveness stems from a creative partnership with the U.S. and international scientific community (including its 55 member universities) and the Federal science establishment. With respect to NCAR, as well as in other activities, UCAR has two functions, first as planner and manager, and second as innovator and initiator.

Under successive contracts with the National Science Foundation, UCAR has managed NCAR since 1960. The Scope of Work of the UCAR-NSF contract assigns to UCAR responsibility "for the management, operation, and maintenance of the National Center for Atmospheric Research and for the *initiation, planning and execution* of its programs and activities" (emphasis added). The Scope of Work further states, "The selection of programs will be based upon their scientific relevance and importance and often upon the need for long-term, large-scale coordinated efforts among atmospheric scientists and a need for complex facilities and logistic support which makes such programs beyond the scope of individual universities."

This assignment of responsibility, far broader than in most government-contractor research relationships, recognizes that if the university community, acting through the Corporation, were deeply and continually involved in the conception and design of the Center's programs, its participation in research of importance to the nation would be greatly enhanced. And this has been the case.

Through the work of the UCAR Members' Representatives, the UCAR Board of Trustees, and the staffs of UCAR and NCAR, university scientists are enlisted to advise on the planning and execution of NCAR programs. They participate in a program that evaluates the effectiveness and importance of all of NCAR's activities in a three-year cycle; and they participate in activities that guide NCAR's relations with and services to the university community.

The following points summarize the value of UCAR to the nation in the planning and operation of NCAR:

- UCAR is composed of virtually all U.S. universities with Ph.D. programs in atmospheric sciences. Member institution faculties are not only deeply involved in the programs of NCAR but have an intense commitment to and pride of ownership in the Center deriving from their governance of it.

- Effective program management of NCAR is provided by a prestigious, legally responsible, university-based Board of Trustees. The Board, through a diversity of membership, gives NCAR expert direction in the design and execution of its programs and administrative functions, as well as overseeing all other Corporate programs. Additional details of UCAR's governing system are included as a separate appendix to this testimony, entitled "The Governance of UCAR".

- Participation by universities in UCAR affairs has created a communications network that ensures an effective university voice in the planning, budgeting, and direction of NCAR. The balance among NCAR activities, especially between research and facilities, is a subject receiving continuing attention within this network, as well as by the UCAR Board of Trustees.

- The community-based peer evaluation structure created by the UCAR member institutions and involving the UCAR Board of Trustees--the Scientific Programs Evaluation Committee and its review panels--is consistently comprised of distinguished scientific leaders in every area of the atmospheric sciences, and is highly credible.

- A great deal of intellectual wisdom is contributed voluntarily by members of the Board of Trustees and many other university faculty and administration officials, both individually and through committee work. These large amounts of time and talent committed for evaluative and advisory functions ensure NCAR's and UCAR's activities are of the highest quality, properly focused and directed. During calendar year 1985, nearly 3 000 person-days of onsite consultation were contributed, without compensation, on the entire range of UCAR activities. We conservatively estimate that an equal amount of time was contributed in both preliminary study and analysis of issues, and in follow-up actions. This represents a substantial enhancement of the public investment in UCAR activities.

- UCAR provides an atmosphere at NCAR in which the highest-level scientific talent can be recruited and retained.

- UCAR provides efficient, highly responsible financial and administrative management. Every annual audit conducted during the 25 years of UCAR operation has resulted in a "clean" audit report.

- UCAR is in a position to ameliorate tensions within the atmospheric science community that otherwise might be explosive, especially in tight budget times. This occurs because UCAR is both a formal and an informal forum for community-wide discussion about NCAR programs and funding levels in light of the overall resources available to academic atmospheric research.

The UCAR Board of Trustees.

UCAR's 15-member Board is elected by the representatives of the member institutions of UCAR for staggered three-year terms. The Board recruits and engages the President of UCAR, authorizes the appointment of the NCAR Director and division directors, sets financial, personnel, and management policy for NCAR, and establishes program direction, priorities, and budgets.

Among current or former Trustees are several present or past university presidents, a former Science Advisor to the President, a former president of the National Academy of Sciences, two former NSF Directors, eight presidents of the American Meteorological Society, former Administrators of NASA and NOAA, the Director of the NASA Goddard Space Flight Center, a former Congressman and director of the Office of Technology Assessment, and many leaders in academic research and university administration. Current Board membership is shown in Attachment 3.

The Board of Trustees is organized into several committees, which meet in conjunction with the full Board and at other times as necessary. Through these mechanisms, as well as through the full Board, all aspects of NCAR's research activities and administration are reviewed. This includes taking any actions that may be required due to budget reductions or increases. Not only does the Board move immediately to confront any budget reductions that may affect the immediate year's research program, but also acts to project necessary program and administrative reconfigurations, including starting new research programs within constant or declining budgets.

Executive/Budget and Program Committee. This committee is responsible to the Board for reviewing, and where necessary, reformulating all NCAR plans and budgets throughout the budget cycle. The committee's job is to ensure that plans brought before the Board, and subsequently submitted to NSF, are soundly conceived, appropriately innovative, consonant with the mission of the Center, directed at the most important opportunities and challenges in the science, and responsive to the needs of the university community and the national interest.

Nearly two years before the beginning of a fiscal year, the committee reviews management's recommendations for program emphases and its analysis of the current base program, anticipated evolutionary shifts in the base program, priorities of proposed new initiatives, and how these initiatives can be incorporated into the base program, even at level or declining funding. It also discusses with management how budget developments regarding earlier fiscal years have influenced the formulation of current proposal.

In these deliberations, the committee examines a broad range of questions, including the balance of resources among the various activities of NCAR; the degree to which the overall NCAR program responds to the long-term needs of the nation; the soundness and innovativeness of the research and facilities programs; the responsiveness of NCAR to university needs, especially those NSF-supported activities that require major research or facility support from NCAR; the maintenance of NCAR plant and capital equipment; and other matters drawn to the committee's attention by the Board, management, NSF, SPEC reviews, or the informal communications network that exists throughout the atmospheric science community.

In subsequent meetings prior to the beginning of the fiscal year, the committee and the Board review and approve budget requests and program plans to be submitted to NSF, with changes necessary for changed budget levels, scientific progress and opportunities, and developments in the scientific community NCAR serves. Once again at this time the Board and the committee will examine the soundness of NCAR's programs, important national and international atmospheric research initiatives, and the needs of the university community.

Personnel Committee. This committee has cognizance over the formulation and application of all UCAR personnel policies, among which are the following: setting salary guidelines, reviewing annual salary actions and the performance evaluation process; reviewing policies on scientific appointments, benefits, retirement, affirmative action, and visiting scientists; setting proportions of scientific appointments among various classes of staff and visitors; reviewing and approving recommendations for the appointment of NCAR Senior Scientists and division directors; and reviewing personnel-related audits and management's responses.

Scientific Programs Evaluation Committee. Community-based peer evaluation of the Center's programs is carried out on a three-year cycle by the UCAR Scientific Programs Evaluation Committee (SPEC) and its review panels. This is a committee of the Members' Representatives and involves the Board of Trustees. UCAR has consistently enlisted distinguished scientific leaders in every area of atmospheric research to serve on the panels. Members of these review panels are appointed by the SPEC in consultation with NSF. Responding to specific questions from NSF is part of the review panels' responsibilities. Among the aspects of NCAR programs examined by the SPEC panels are the following:

- The appropriateness of the NCAR division's activities, priorities, budgets and plans in the context of national needs, the missions of NCAR, and the division's goals as defined in NCAR program plans and long-range plans.
- The quality, innovativeness, and productivity of scientific and technical workin with the division.
- Effectiveness of the use of resources and whether those resources are appropriate for the tasks the division has been assigned.
- Level and effectiveness of joint efforts involving groups and individuals from universities, other institutions, and within NCAR.
- The manner in which the division and NCAR management responded to the previous SPEC review.
- In the case of facilities divisions, such as supercomputing, the balance between operational and development activities, the effectiveness with which the division has served its users, and how resource allocations are made.

The panel reports are submitted to the UCAR President, who sends them informally to NSF as soon as they are received. They are subsequently submitted to the member representatives, along with draft UCAR Board responses to all recommendations, and are then referred to the Board for action and for preparation of final responses for formal transmittal to NSF. As appropriate, NSF sometimes asks for further clarification of the responses. A list of our recent SPEC panels is enclosed as Attachment 4.

UCAR's Role in Equipment Acquisition.

UCAR has used its position as a private non-profit corporation and as a large consortium of universities to acquire scientific equipment and services at costs and under terms and conditions at times not available through traditional government-funded acquisition methods or not available to a single university.

In 1977, UCAR pioneered in the use of its tax-exempt status to finance acquisition of a supercomputer (CRAY 1A) for NCAR through issuance of tax-exempt revenue bonds. The County of Boulder, Colorado, issued the bonds on behalf of UCAR and the Colorado State University Research Foundation guaranteed the bonds. As a result, NCAR and the university community which is served by NCAR research facilities reaped the scientific benefits of a fivefold increase in computing power for a savings to the government of 15% over the costs of a conventional vendor lease/purchase agreement. UCAR is now in the final stages of concluding a third-party purchase and lease arrangement whereby an advanced vector computer (CRAY X-MP 4800) will be installed at NCAR under the terms of a six-year lease to UCAR. At the end of the lease period the computer will become the property of the government. Given the manufacturer's position that it would directly lease the X-MP 4800 to UCAR for a maximum of three years, the third-party arrangement for a longer period made it budgetarily possible for UCAR and NCAR to acquire the computer.

On behalf of the university atmospheric sciences community, UCAR has used its purchasing power to pool university equipment and data needs in order to obtain quantity price discounts. For example, in recent months, UCAR has concluded an agreement with a company which redistributes realtime weather and satellite data. Under this arrangement, universities will be able to receive satellite weather data at their campus locations (approximately 20 universities have signed up for the service to date) at about half the cost they would otherwise have to pay on an individual basis.

UCAR's Relationships with NSF.

UCAR and NSF are engaged in constant communication and close coordination on program planning, scientific and administrative management, and contractual matters.

UCAR invites, and NSF sends, official observers to all meetings of the Board of Trustees, the Board's Budget and Program Committee, and the annual meeting of the member representatives. NSF observers participate actively in discussions at meetings of the Board and its committees.

UCAR conducts its April Board meeting at NSF headquarters each year, thereby permitting both formal and informal interaction among the Director and staff of NSF, UCAR Board members, and UCAR and NCAR staffs. At this time, and at other times throughout the year, the NSF Director is briefed on UCAR and NCAR activities.

UCAR and NCAR staff are invited by NSF and participate in the relevant NSF advisory committee meetings affecting atmospheric sciences, computing, and other matters. In addition, joint planning workshops involving NSF, UCAR, and NCAR leadership are convened.

In addition, there are a variety of other interactions, ranging from submission of various reports and planning documents in accordance with contractual requirements, to daily, informal interactions over the telephone between UCAR, NCAR, and NSF staff at all levels, as well as personal consultations both in Boulder and in Washington.

These events combine to shape the NCAR program, ensure that UCAR programs are consonant with the activities of NSF, and assure NSF that UCAR's program and administrative planning and management performance are appropriate to the aims of the Foundation and to the highest management standards.

VI. BUDGET IMPACTS

This section comments on the impacts of recent and anticipated budget reductions on the NCAR program. At the outset I want to make it clear that we do not feel ourselves singled out in having to make very difficult budget decisions and to reduce, delay or eliminate activities that would be of benefit to science and the nation.

I would be disappointed if the Subcommittee viewed this analysis as a complaint. I present it, at the request of your staff, so that you can have a clear view of the situation at NCAR and to give you additional information to assist you in making difficult budget decisions.

Budget Actions in FY 1985-86.

You are, of course, well aware of the importance of "supercomputing" in science, and this is truer of atmospheric science than many other disciplines. This is discussed in a later section of my testimony entitled "Supercomputing Facilities at NCAR". It is sufficient to say here that the essentiality of supercomputing is dictated both by the complexity of realistic mathematical models of the earth's climate, the circulation of the oceans and similar systems, and by the necessity to process and analyze vast amounts of data generated by radars, satellites, research aircraft, and other means.

In FY85, the National Science Foundation responded to UCAR's request to begin the funding for a supercomputer to serve NCAR and the university community. The justification for this system, which we will be installing at NCAR this summer, was developed and supported by the entire community, and was endorsed by the UCAR Board of Trustees. This acquisition did not come "for free." In order to accommodate the computer funding within the total budgets assigned to us, we had to reduce NCAR programs in other areas. Similar decreases occurred in the NSF atmospheric science grants programs in order to make the acquisition possible. The system is thus being acquired because the community as a whole assigned it the highest priority.

A further adjustment in our program occurred in FY85-86. Guided by discussions with the Foundation and under directives of the Board of Trustees, the need was clear to increase the level of effort in various areas of science (for example, the chemistry of the lower atmosphere) and to continue to update NCAR facilities and other programs that serve university scientists.

As a result of the computer acquisition and this reprogramming, we cut back programs in other areas. We reduced NCAR's capability to manage and support field programs in the study of severe storms; we eliminated a leased aircraft; and we cut back NCAR's programs in stratospheric chemistry, solar studies, and atmospheric dynamics and turbulence. All of these had been judged to be of the very highest quality by external reviewers and were expected to yield important research results in the future. As a consequence, of these actions, we eliminated approximately 35 positions in NCAR in these areas.

We narrowed the NCAR program with some trepidation. Science is a realm filled with surprises. An area of science not previously considered of high importance can suddenly be of the greatest relevance not only to science but to the nation. Twenty-five years ago, the relevance of stratospheric chemistry was not clear. Yet fifteen years later, policy makers were urgently seeking answers to questions about the influence of fluorocarbons on the protective ozone layer in the stratosphere. Because the scientific community had started a program in stratospheric chemistry a decade earlier, we were ready to deal with these requests. It is unfortunate that we must now cut back this program.

The same can be said of the study of the interactions of the atmosphere and the oceans, which was once thought to be of mainly theoretical interest in the study of the nature and origins of climate. Suddenly, a few years ago, scientists began to see connections between anomalies in the tropical oceans (the so-called El Nino) and the strange winter weather that a short time later afflicted the United States and other regions of the world. This discovery led us, in turn, to new approaches to studying the potentiality of season-ahead climate prediction.

The lesson of all this is clear. In basic research, it is wise to keep the approach broad, and to stay active in areas of science even when connections to other areas of science or to applications are not immediately apparent.

Nonetheless, the Board of Trustees directed NCAR to move ahead to narrow the focus of the program. Given the choices faced, it was clear that it was essential for NCAR to maintain powerful programs in fewer areas of research and facilities, even at the expense of giving up or trimming high-quality efforts.

This was the condition going into FY86. NCAR is a lean, highly focused organization, having already pared away quality and value. In addition, we have imposed, on a one-year basis only, a salary freeze on NCAR's entire staff. This occurred before Gramm-Rudman.

As a result of the Gramm-Rudman legislation, we expect that on March 1, UCAR will be told to NCAR's our FY86 budget by an additional 4.3%, or about $1.9 million. We are now taking action to do this by deferring equipment and other purchases, deferring maintenance and short-term visitor appointments, and keeping most vacancies open.

Effects on NCAR of the Administration's Budget for FY87.

This analysis is based on informal information we have received from the NSF staff concerning the funding NCAR would receive in FY87 if the President's budget were adopted. The increase in current dollars for NCAR from FY86 to FY87 translates into a level budget in real dollars, at best. Within this level budget, NCAR faces a $1.5 million increase in its computing budget, according to the agreed-to funding schedule for the X-MP supercomputer. Further, in accord with community-wide priorities endorsed by the UCAR Board, we have agreed with NSF to new initiatives in atmospheric chemistry and computing science and engineering. Therefore, at the President's level, we will have to find, somewhere in the NCAR program, approximately $4.5 million in cuts. This amounts to a reduction of more than 10%, and will result in significant narrowing of NCAR's program and layoff of staff at all levels.

NCAR's detailed plan for FY87 is still being formulated by our staff and by the UCAR Board of Trustees, so the picture I will sketch for you is preliminary. However, our solution will not differ substantially from what I will describe. The following steps will typify our solutions.

- We will reduce our research programs in four major areas of atmospheric research: stratospheric chemistry, the sun and its interaction with the earth's atmosphere, the nature of clouds and precipitation, and the aspects of the study of climate. As previously stated, all these studies have been deemed by outside reviewers to be of high excellence and importance.

- We will take out of general service our CP-2 Doppler radar, the most versatile such instrument in existence, which has been widely used in field programs in many parts of the nation. This will affect the community's ability to conduct studies related to the understanding and prediction of severe local storms, as well as other studies.

- We will take substantial reductions in NCAR's computing division. We will keep our supercomputing initiative going, but to the extent compatible we will cut the services and assistance we render to our users across the country, and we will dispense with several supporting hardware systems.

Impacts if Gramm-Rudman reduces NCAR budgets further in FY87 and subsequent years.

We have heard reports that Gramm-Rudman may result in a decrease in science budgets of as much as 25% over the next two to three years. The UCAR Board of Trustees is now conducting a serious study of the implications of a reduction on the order of 25% in NCAR's budget.

It is clear that such a cut would force the National Center to become a different institution. We would have to take actions such as the following:

- abandon NCAR's supercomputing initiative;
- reduce NCAR's field facilities substantially; and
- narrow NCAR's focus by eliminating entire fields of research.

We would be designing a program that would be concentrated in only a very few areas of research, and we would abandon the concept of NCAR as a broad-based institution providing support and national leadership in many important areas of atmospheric research.

In this scenario, NCAR would be forced to eliminate from among such fields as:

- the chemistry of the atmosphere, including studies such as acid rain;
- the nature of climate and the impacts on climate caused by the
- activities of mankind;
- the variability of the sun and its possible impacts on climate;
- the nature of severe storms, and the possibility of improving
- warnings and predictions;
- the interactions of the atmosphere with the oceans and plant and
- animal life; and
- the impact of human activity on air quality.

NCAR's collaborative programs would be preserved in only a very small number of such research areas. For other areas, only research on the single-university scale would remain, and much of the collaborative research essential to progress in these areas would go by the board.

There would also be a serious effect on the facilities that NCAR provides to the national research community. As stated earlier, one of NCAR's primary missions is to develop and provide advanced facilities. Clearly, however, NCAR could not provide adequately facilities in both computing and field experiments. Since both are essential to a healthy national program in atmospheric research, the choice would be devastating, whichever way it was made.

In summary, if the Gramm-Rudman reductions over the next few years are as severe as many of you have said, it is obvious that the National Center, as well as the Federally supported research programs of the universities, would have to be greatly reduced and redesigned. The goals of the remaining program would be far out of line with the information needs of decision and policy makers. And the societal benefits that would come from our field of research would be dramatically curtailed in some areas and completely halted in others.

VII. OTHER ACTIVITIES OF UCAR

The National Scientific Balloon Facility.

The National Scientific Balloon Facility (NSBF) was established by NCAR in the early 1960s. Since 1983, UCAR has managed the NSBF under a contract with NASA. The Facility provides balloon flight and support services for scientists working in atmospheric science, astronomy, physics and other disciplines.

The NSBF launches balloons from its base near Palestine, Texas, and from remote sites around the world, tracks them with aircraft and navigational devices, and sends chase crews to recover the instrument packages after the packages are parachuted back to earth. The Facility's technical staff conducts research and development work to improve scientific ballooning technology.

Other UCAR Projects

Until a few years ago, almost all of UCAR's attention was devoted to the management and operation of NCAR and the NSBF. In 1982, the UCAR Member Representatives adopted the Corporate Prospectus which set a goal for UCAR to broaden and strengthen its effort to advance the atmospheric sciences on behalf of the university community and the nation, beyond the management of NCAR and NSBF. Since that time, UCAR has made significant progress toward achieving this goal, and UCAR intends to continue to advance this trend. Hundreds of university scientists have been involved in these new UCAR activities, all of which are aimed at benefiting the university community and meeting the scientific needs of the nation. Attachment 5 is a list of several hundred scientists who have been active in these other projects. A brief description of some of these projects follows.

Computer Science Network.

UCAR continues to develop and manage the Computer Sciences Network (CSNET) under contract with the NSF. This is a communications network now enabling computer scientists at 170 university, industrial, and government laboratory sites to communicate through a common linkage. Virtually all UCAR member institutions are part of this network, which is approaching being self-supporting principally from annual membership fees. UCAR will continue to manage this activity for the near future, and provide input to the planning of a national scientific communications network being developed under the aegis of the Foundation in connection with the establishment of Super Computer Centers.

UNIDATA.

Project UNIDATA (UNIversity DATA) is a splendid example of the UCAR university community working together to produce efficient and innovative solutions to problems which each university faced individually.

When the National Weather Service announced, in 1982, the planned phase-out of the delivery system by which universities obtained current weather data for their research and instructional needs, UCAR, with the encouragement of NSF, was asked to investigate ways of acquiring and delivering such crucial information to the university community. UCAR established a number of working groups comprised of university and NCAR scientists to consider communications strategies to replace the Weather Service system. This community approach to finding solutions to an immediate problem facing the individual universities produced far-reaching dividends. The university community quickly realized that the communications technologies that might be appropriate for delivering weather data to a widely dispersed group of universities were not unlike technologies which would enhance the communications between computing systems at the different universities, or, for example, between the universities and NCAR's computing facility. Thus, the UNIDATA working groups expanded the task before them to include the design of a major enhancement to the existing system providing university connection to supercomputer facilities.

Project UNIDATA has therefore evolved along two closely related pathways. A system has been established to provide weather data, weather satellite imagery, and weather radar reflectivity data to universities by way of a satellite broadcast system, under a UCAR-negotiated contract with a private communications company. Local (i.e., university site) protocols have been developed to receive and ingest the data, and to provide for database management, processing, display, and archiving. In addition, the UNIDATA Project has developed recommendations for computer hardware requirements appropriate to several kinds of university research and instructional needs. The project is involved with development of crucial software to support the communications, and provides technical services and assistance to those university groups which request it.

At this time, weather data is being received at some forty universities, and the number is expected to grow to about 100 in 1987. In addition to the weather data delivery system of Project UNIDATA, Project scientists and working groups have designed the essential details of a complex communications system linking university computing systems with each other, and with the computing facility at NCAR.

In a closely related development, NCAR is conducting an NSF-sponsored experiment in high speed satellite communications links between its supercomputer facility and university-based local-area-networks (LAN) for efficient interactive research involving major supercomputers. This computer communications system will allow university scientists to have a more efficient, two-way communications with NCAR's computing facility (and university-to-university computer communications), which will further enhance the research capabilities of the UCAR community.

The UCAR UNIDATA Project has stimulated discussions with several private companies to transfer computer, communications, and other technologies into university-based research and education. The UNIDATA Project focused on the difficult technical problems of delivering large, real-time data, archival data, and research data sets to university users, and of linking centralized supercomputing facilities, such as NCAR's, to a large community of universities spread across the country. Not surprisingly, several large computer and communications companies have keen interests in solutions to the same technical problems, and in interfacing their hardware and software products with the unique UNIDATA configurations. UCAR is therefore taking the initiative to stimulate developments and cooperative projects bridging between the university and the private sectors. Discussions are in progress, for example, to secure private sector cooperation in LAN graphics workstations, interactive computer-videodisc instructional systems, and local data storage and distributions technology. These are ventures which clearly complement and accelerate the investment of the Federal government in research and educational technologies.

Visiting Scientist Program.

A UCAR Visiting Scientist Program has been established at the Naval Environmental Prediction Research Facility (NEPRF) and the national prediction centers of the National Weather Service. These programs are intended to improve the quality and effectiveness of these Federal laboratories by entraining university faculty and postdoctoral scientists into the programs of the laboratories. Under UCAR auspices, the visiting scientists undertake basic research on problems related to the concerns of these two operational prediction facilities. The first UCAR team of research scientists has begun work on improvements to forecast models at the NWC National Meteorological Center, Camp Springs, MD; the first UCAR Visiting Scientist appointment is being made at NEPRF. Both the agencies and the universities benefit through this broadened program of interaction.

Planning major new initiatives.

On the national level, UCAR is involved in a broad spectrum of research planning in the atmospheric and ocean sciences. Four of the major activities in this area are STORM, the International Global Tropospheric Chemistry Program, the NASA Earth Sciences Study Committee, and the Global Biosphere-Geosphere Program.

The STORM (or Stormscale Operational and Research Meteorology) Program is based on the premise that the necessary scientific and technical resources are available today for substantial improvement of the nation's systems for detecting and predicting disruptive and severe weather. The program focuses on mesoscale, or stormscale, weather that frequently takes lives and causes sizable economic losses, such as violent thunderstorms, tornadoes, flash floods caused by rain, and heavy snowfalls. This is a multi-agency multi-year effort to improve prediction.

The Global Tropospheric Chemistry Program is aimed at developing a needed understanding of the fundamental chemistry of the lower atmosphere. Advances in this area are critical to understanding the greenhouse effect of trace gases such as carbon dioxide and methane, now thought to be the dominant factor in climate change in the next half century.

The Earth Sciences Study Committee was organized by the NASA Advisory Council to draft a plan that would integrate efforts of all earth sciences, including biology, to make optimum use of satellite technology and the capacity of modern computers to model coupled systems. The study involves interests of other agencies as well, and for this reason the Committee is also making recommendations for participation by NOAA and NSF. UCAR is providing scientific and administrative support to this committee.

The International Global Biosphere-Geosphere Program, now under study by the National Academy of Sciences and the International Council of Scientific Unions, is the realization of an effort seen long ago at UCAR as central to the national need: a movement to develop multidisciplinary research in key areas to strengthen our understanding of the earth as a coupled system of living and non-living parts. The envisioned multidisciplinary program, lasting 10-20 years, would require collaboration of many disciplines and the cooperation of many nations with the goal of defining impending changes in the global environment. UCAR is providing national leadership for the IGBP and ICSU studies, as well as a point of contact for the atmospheric sciences in that effort through a new Office for Interdisciplinary Research.

International Activities.

UCAR has been involved in a broad range of planning and research activities on the international level. Examples of such activities are the following projects.

- Formation of a new UCAR International Affiliates Program to strengthen contacts with premier atmospheric research institutions abroad and to encourage international cooperation in science.
- Work with NOAA to organize and conduct a series of workshops and conferences to plan activities for the Tropical Oceans and the Global Atmosphere (TOGA) program. UCAR is now providing logistical support for U.S. scientist involvement in a 4-year series of U.S.-People's Republic of China oceanographic expeditions which began in 1986.
- U.S.-India science and technology initiative for monsoon research was agreed to by the two countries in 1984. UCAR, with funding from NSF, has provided support for U.S. participation in this effort.
- A second effort, involving a joint U.S.-People's Republic of China project to study the winter Southeast Asia Monsoon, is underway.
- Discussions are underway with NSF about providing logistical support for an expedition to the Western Pacific to study the next total solar eclipse in 1988.

Improved Precollege Education in Science and Mathematics

In cooperation with the American Meteorological Society, this nation's leading professional society for atmospheric, oceanic, and related sciences, UCAR has prepared a comprehensive plan to improve pre-college science, math, and technology education in the nation's school system. This activity is being developed in response to the national crisis in pre-college education, which was acknowledged by the National Science Board's Commission on Pre-College Math, Science, and Technology Education. UCAR perceived that it was in an excellent position to make a strong impact on the pre-college science educational crisis, owing to its strong university organization, and to the fact that the atmospheric sciences represents an excellent vehicle for teaching physics, chemistry, math, computer sciences, and engineering fundamentals.

The proposed plan calls for working interactions between the UCAR universities and the pre-college educational sector to develop instructional materials. Furthermore, because of our links with the private sector, the plan calls for development of educational activities in cooperation with the commercial and public television broadcast sector, and work with private companies to transfer computer and interactive-computer-videodisc teaching technology into the pre-college educational environment. This technical development is a natural spin-off of UCAR's efforts in Project UNIDATA, and UCAR is in an excellent position to see that such technology is transferred into our high schools and junior highs. Our goal is to secure approximately 50-50 participation between Federal and private sector funding for this effort. We believe that the UCAR-university-private sector collaboration provides crucial leverage for obtaining acceleration of the public investment in education.

VIII. TECHNOLOGY TRANSFER AND THE U.S. PRIVATE SECTOR

One of UCAR's objectives is to organize and develop ventures between our scientific constituency and the private sector, for the mutual benefit of both. A major program is already well underway to achieve this.

Corporate Affiliates Program.

UCAR is carrying out an aggressive and self-supporting program of technology and information transfer to the U.S. private sector through our Corporate Affiliates Program (CAP). The program objective is to help to improve the competitive stance of U.S. corporations.

This program is dedicated to linking the atmospheric and related sciences community and the U.S. industrial sector in a way that will transfer new technologies, scientific advances and the latest information on critical scientific issues and trends, from the research community to industry. It is also structured to bring to the university community an awareness of industry's needs and interests, and to facilitate scientific exchange and collaboration with industry scientists and corporate managers. The Program, self-sustaining from the $10,000 annual fee assessed from its corporate membership, supports a small, but effective staff whose job it is to deliver a series of services in support of the program objective.

The CAP Information Service enables member corporations to keep current in topical areas related to UCAR's scientific and technological endeavors. This special Service tailors scientific information to a company's specific needs, as well as responding to specific requests for information and expertise. In addition, it provides general information of interest to the company on a routine basis.

An annual CAP Symposium is held for our corporate affiliates on one or more topics in which the companies have expressed a desire for indepth knowledge. The Symposium is conducted by leading experts in the particular field from the UCAR universities and NCAR, and may include presentations by the companies' experts. Over the past two years, our CAP Symposium has covered artificial intelligence applications, the greenhouse effect, and aviation safety.

In addition to our annual Symposium, a special briefing is available each year to each of our member corporations. A UCAR team, comprised of NCAR and university scientists, will visit an affiliate company, or host the company personnel at the UCAR facility. The presentation is tailored to the interests and needs of the company, and the team confers with the company's management and R&D groups as part of the effort.

Another feature of our Corporate Affiliates Program is the CAP Referral Service, providing comprehensive lists of resources within the universities and NCAR that can be brought to bear on specific problems faced by an affiliate company.

We have 14 corporate affiliates active in our program, and another half a dozen have expressed interest. Our present members include the following: Atlantic Richfield; Burlington Northern; General Motors; IBM; RCA; MITRE Corporation; Weyerhaeuser Company; Sperry Corporation; Digital Equipment Company (DEC); the Aerospace Corporation; Deere & Company, WSI Corporation; Planning Research Corporation; and the International Center for Aerospace Sciences & Technology.

As a direct result of our Corporate Affiliates effort, both Burlington Northern and MITRE have asked UCAR to develop joint projects with them.

IX. SUPERCOMPUTING FACILITIES AT NCAR

We have been asked by the Subcommittee to comment on the management of NCAR's supercomputing facilities.

Since its inception, NCAR has worked to be at the forefront of large-scale computing, in order to provide adequate capacity for the computer-intensive work that is at the heart of atmospheric research. NCAR has consistently acquired early production models of the fastest computers available. It has pioneered in development methods to provide computing service for visiting scientists and to allow scientists to run large computing jobs on the NCAR computers from their home campuses. And it is now engaged in an NSF-supported experiment in satellite communications, in order to make remote use of the computers by university scientists even more efficient.

It has been essential to the advancement of the science that NCAR develop the most advanced computing capabilities obtainable. Both modeling efforts and the necessity to process and analyze vast amounts of data have put ultra-high-speed computing at the top of the priority list for atmospheric research facilities. Without such capabilities, we would not have achieved many of the advances of the past two decades that I have discussed previously.

NCAR provides computing support to approximately 1,000 users each year, the bulk of them at universities. Remote computing service is provided to scientists at approximately 140 locations throughout North America.

An example of the innovative use of high-speed computing at NCAR is the NCAR Community Climate Model. This is a model which is fully documented and which allows NCAR and university researchers to carry out a broad range of experiments. These range from an examination of the warming of the earth's atmosphere that will result from increasing levels of carbon dioxide in the atmosphere, to explorations of the development of the earth's atmosphere through past geological eras (a study which, as a by-product, has indicated parts of the earth that may contain undiscovered oil deposits).

The method of allocating NCAR's computer resources to the national user community is as follows. The UCAR Board of Trustees has adopted an overall policy of allocating approximately half the resource to the university community and half to the NCAR scientific and facilities staff. The university portion is allocated with the advice of the Scientific Computing Advisory Panel, which is composed of scientists from universities and research institutions across the country. Requests from university users are reviewed at semi-annual meetings of the panel. Their review ensures that problems proposed to be run on the NCAR computers are well-formulated scientifically and designed to use the resource efficiently. The NCAR portion is allocated by the Director of NCAR as one of several means of guiding the overall NCAR program and ensuring that it is designed to pursue the goals of NCAR with the greatest effectiveness.

Like all other activities of NCAR, the performance of NCAR's Scientific Computing Division is reviewed every three years by a panel of outstanding scientists from across the nation. These reviews have consistently praised the services provided by the Division and the importance of the science the facility serves.

X. THE INDEMNIFICATION ISSUE

UCAR has experienced the same difficulties during the past year as many other universities, corporations, and school systems throughout the country in obtaining renewal of certain of its third-party liability insurance. In our case, we had difficulty in obtaining continued coverage for NCAR flight operations (supported by NSF; $50,000,000 coverage) and for NSBF balloon flights and tracking aircraft operations (supported by NASA; $100,000,000 coverage). The insurance was provided by a Lloyds of London group of reinsurers. Lloyds had indicated it would discontinue the coverage on September 30, 1985, due to heavy losses sustained in the aircraft industry in 1985 and in particular due to the presumed risk of operating NCAR's Electra (Lloyds had the coverage on the Galaxie Electra that crashed in Nevada). This was in spite of our first-rate safety, pilot training, and maintenance record. After months of negotiation, we were able to obtain a series of extensions through November 30, 1985.

A transatlantic conference call among the representatives of Lloyds in Chicago and London, UCAR's insurance broker (Marsh & McLennan), and NCAR and UCAR staff was held and the steps NCAR had taken following the crash of the Galaxie Electra to determine the air worthiness of the NCAR Electra, and NCAR's ongoing maintenance and pilot proficiency programs to maximize the safety of our Electra operations, were described in detail. Following this conference call, Lloyds agreed to provide an additional twelve months' coverage beginning December 1, 1985. However, the premium for the renewal period was raised to $150,000, an increase of 28% over the 1984-85 premium costs. A chart showing the premiums paid by UCAR from FY80-FY86 for third-party liability insurance on both NCAR flight operations and NSBF ballooning follows below.

As the shake-up throughout the insurance industry continues, insurance can be expected to continue to rise in cost, or become unavailable altogether, as for our Terminal Doppler Weather Radar Program requested by the FAA.

As a result of the windshear-caused commercial aviation accident at the Dallas/Fort Worth Airport in August, 1985, the FAA has asked UCAR to continue its windshear/terminal Doppler radar research program. In developing and submitting the proposal to the FAA, however, we surveyed the market to find insurance to protect both UCAR and our scientist-employees developing the software and hardware linkages for large airport terminals. After several months of inquiry, we have not been successful in placing this insurance, even though we use the largest and best-known insurance broker in the country. We are faced with a circumstance where we have already completed some of the R&D work, tested some of the technology and software successfully under previously-sponsored FAA contracts; demonstrated a capability for predicting windshear and microbursts, and the insurance necessary to provide coverage for an operations test, the results of which could save the insurance industry millions of dollars, is not available. This will force us to apply to the FAA during the next few weeks for indemnification under Public Law 85-804. This statute and the related Executive Order (No. 10789) permit the Secretary of Transportation to indemnify and hold UCAR harmless against claims or losses arising from our participation in the FAA Terminal Doppler Project as long as the Secretary finds that indemnification will facilitate the national defense and the risks associated with the project are "unusually hazardous" in nature. We believe we can demonstrate both points.

NSF is not covered by this statute and executive order, and therefore would have to seek legislative action to provide indemnification for our aviation facility should we be unable to obtain future coverage. UCAR is not asking NSF to consider taking such action at this time. If present trends continue in the insurance industry, however, we may have to make such a request in order to continue our research.

The chart showing UCAR's increase in premium coverage from FY80-FY86 follows.

Premiums for UCAR
Aviation Third-Party Liability Insurance

	FY80	FY81	FY82	FY83	FY84	FY85	FY86
Aviation	$43,270	45,191	48,750	46,000	62,000	72,600	120,000
Ballooning	39,000	43,250	43,250	54,000	46,000	47,400	30,000*
TOTAL	$82,270	$88,441	$92,000	$100,000	$108,000	$120,000	$150,000

*Due to technical problems, roughly half as many balloon flights as in previous years are scheduled for FY86. The reduced premium cost reflects this circumstance.

Mr. Chairman, this concludes my testimony. I would be glad to answer any questions you may have.

End of testimony

3 April 1986

RESPONSES TO QUESTIONS FROM THE HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY ADDRESSED TO DR. CLIFFORD J. MURINO, PRESIDENT, UCAR, ON 6 MARCH 1986.

Questions Addressed to All Presidents of Consortia

Question 1: Please provide for the record a brief summary of:

a. the percent of the consortium's total budget provided by NSF;

Response: Approximately 68% for FY 1986.

b. the portion of the consortium's management or consultant fee received from NSF, compared to funds for research, and for facility maintenance and upgrade;

Response: We assume that the question concerns funds for the National Center for Atmospheric Research (NCAR). Further we interpret the phrase "management or consultant fee" to include corporate overhead (corporate central administrative expense) allocated to NCAR as well as the annual fixed fee paid by NSF to UCAR for management of NCAR. Finally, we assume that the phrase "funds for research, and for facility maintenance and upgrade" refers to the total of NCAR's annual funds except for overhead and fee.

In FY 1986, it is estimated that UCAR will receive the following funds for management and operation of NCAR:

	NCAR Funds	UCAR Overhead	UCAR Fixed Fee
FY 1986 NSF Funds*	$43,554,000	$752,000	$75,000
FY 1986 Other Agency Funds*	11,434,000	188,000	--
Total	$54,988,000	$940,000	$75,000

*Includes carryover funds from FY 1985.

Thus, the portion of UCAR overhead paid by NSF in connection with NCAR represents 1.7% of NSF funding of NCAR (or 1.4% of total funding of NCAR).

c. The portion of the consortium's funds allocated for overhead and what that overhead includes;

Response: It is assumed that "overhead" refers to corporate central administration expense, which is allocated through a general and administrative (G&A) rate, approved by NSF, to all UCAR activities. In FY 1986, it is estimated that UCAR central administration expense will be $1,218,000. This amount represents approximately 1.8% of total FY 1986 UCAR funds.

UCAR central administration includes the Office of the President of UCAR; the Office of Corporate Affairs (including activities of the UCAR Board of Trustees and its committees, the Members Representatives of UCAR and their committees, corporate program liaison with NCAR, NSBF, CSNET, etc., and UCAR budget and planning policy); the Office of Finance and Administration (including financial management, personnel, and administrative policy development and oversight, external auditing, capital financing, commercial banking, prime contract negotiation and administration, corporate budget development and oversight, and other corporate treasurer functions); the Corporate Counsel; and the Corporate Auditor.

d. the membership fee the consortium charges to participating universities and how the fee is utilized by the consortium;

Response: UCAR charges a one-time fee of $3,500 to entering members. These fees are credited to the corporation's General Fund, which constitutes its reserve. This fund is held for such items as contingent liabilities; seed money for scientific endeavors; assistance to NCAR to meet unexpected budget crises (in FY 1986 up to $125,000 of this fund has been made available to NCAR to provide special assistance related to FY 1986 budget reductions); and necessary corporate expense not chargeable to government contracts.

e. how are the consortium facilities managed to assure the equipment, instrumentation and bricks and mortar are maintained, and properly renovated? Do the Centers include a separate line item for this end of the operations?

Response: All facilities, scientific as well as physical plant, have maintenance budgets. For example, in FY 1986 NCAR has budgeted approximately $260,000 for aircraft maintenance, $200,000 for radar maintenance, $1,300,000 for scientific computer maintenance, and $300,000 for physical plant maintenance replacement. In addition, approximately $400,000 is budgeted for scientific instrumentation development to keep NCAR's stable of such instruments as close to the state-of-the-art as total funding will allow. Major predictable maintenance needs which require additions to base maintenance funds are sought incrementally from NSF. Emergency maintenance costing up to a few hundred thousand dollars in any given year will be covered by reprogramming. For emergency maintenance requiring greater amounts, supplemental funding would be sought from NSF. Yearly funding for maintenance and instrumentation development appear as line items in annual operating plans approved by NSF.

f. a brief summary of functions or characteristics which are uniquely different from the other NSF large-scale facility management consortia.

Response: UCAR differs from other NSF consortia in terms of the mission agreed to by UCAR and NSF and the fact that it has a very broad membership (55 univerities) that ensures that virtually the whole university-based atmospheric science community is involved in setting the goals and priorities of the corporation and of the National Center. This process results in development of strong constituency support for the UCAR and NCAR programs.

The other NSF national centers were established to develop and operate facilities for the general use of the scientific community. The missions of UCAR and NCAR go far beyond this. Because many crucial atmospheric studies are too large and extend over too long a time to be appropriate to single universities, UCAR's mission is to stimulate and assist the atmospheric science community to identify and tackle those large-scale problems that are of central importance to the science and the nation. This mission is fulfilled through drawing the scientific community into the planning and execution of these efforts and by providing scientific leadership, facility support, and logistic management. UCAR and NCAR, in collaboration with the community, has been involved in the planning and execution of many national and international atmospheric research programs. UCAR therefore serves as a means of focusing the national effort in atmospheric research on those problems of greatest importance to the science and the nation.

UCAR is composed of virtually all U.S. universities that have Ph.D. programs in atmospheric science, while the other consortia are composed of a limited sample of institutions with programs in the relevant disciplines. UCAR's broad membership serves an essential purpose. UCAR's membership constitutes a forum for the achievement of national consensus about future directions for atmospheric research and about the distribution of resources--between NCAR and the universities, and between research and facilities--that will be most effective in achieving the most valuable research progress.

Through UCAR, the national atmospheric research community is deeply involved in setting priorities for the development of new or improved facilities and for the initiation of new research efforts at NCAR. The same involvement promotes broad and effective collaboration among NCAR and university scientists.

Question 2: How much overlap is there among the university members of the various consortia? Is a separate consortium required for each discipline, and why? Could management economies be realized using one university consortium as the management organization for all NSF large-scale facilities?

Response: Even though the consortia are similar in that they are composed of universities, they differ significantly in structure and mission. Their roles have evolved over the years to meet the special needs and circumstances of the disciplines involved.

A separate consortium is essential to achieving national-interest goals in the atmospheric sciences. As stated in my response to Question 1-f, UCAR's goal in the operation of NCAR (and in other efforts) is to move the entire field of atmospheric research forward.

The primary need in atmospheric research is to bring scientists from across the nation into programs that accord with national priorities. The main function of the UCAR Board of Trustees and of the representatives of the Member Institutions of UCAR is to examine priorities within atmospheric research and to put into place the optimum arrangements and allocation of resources to promote the efficient pursuit of those priorities. This activity is, of course, specific to atmospheric research, and therefore not duplicated by the other consortia. It is essential that the examinations of priorities and activities be carried out primarily by atmospheric scientists; therefore, even if NCAR were operated under an umbrella consortium, it would be necessary to expend funds to allow the atmospheric research community to forge a national consensus on the most useful and scientifically promising programs.

This function can only be served by a consortium or other mechanisms which can marshal the expertise, experience and motivation that exists only in the atmospheric sciences community.

Most of the fee and overhead paid by NSF to UCAR is devoted to this broad mission. One of the major ingredients of the overhead UCAR charges is for the expenses of the Board of Trustees, the annual Members' meeting, and the many advisory and evaluative bodies that ensure that NCAR programs are responsive both to the national interest and the needs of the universities.

UCAR has 55 member universities, while the other consortia with which NSF deals have far fewer members. There is considerable one-way overlap in membership--that is, most of the members of the other consortia are members of UCAR, but not the other way around. In each consortium different people from different disciplines are involved.

For these reasons, the economies that might be realized from having an umbrella consortium would not be as great as might be imagined. Further, the price that would be paid would be a diminution of broad community responsibility for the design and execution of the national atmospheric research program and for the quality of the NCAR program. The current arrangements, which ensures broad responsibility and participation, is working well and should continue.

Question 3: NSF's major national research centers provide the entire university research community with access to large, and often unique, research facilities. Operation of the major research centers in astronomy, atmospheric research, earth sciences and ocean sciences comprise about 10 percent of the NSF research budget. Do you foresee growth in the national research centers in order to provide greater access and improved capabilities?

Response: I will restrict my response to atmospheric research.

With respect to the staff of the National Center, we see the need for only modest growth in coming years. However, there is a pressing need for new facilities and for improvements in existing facilities and instrumentation in coming years, to make possible effective attacks on such problems as acid rain and other atmospheric chemistry issues; the formation and prediction of tornadoes, windshear, and other severe weather events; the nature and predictability of climate; and the impacts of human activity on weather and climate.

UCAR believes that continued investment in the research facilities of NCAR will be the most cost-effective means of providing needed large-scale facilities for the universities, particularly for use by the university-NCAR community in major national and international programs.

Among the new or improved capabilities that will be required at NCAR over the next few years are research aircraft, radars and other remote sensing devices, communications networks and data-handling devices to support field experiments, supercomputing capabilities dedicated to atmospheric research, and a broad variety of new chemical and physical observing instruments.

The progress of atmospheric research depends equally on the health of research in the universities themselves. Therefore, improvement in the array of capabilities at the National Center must be accompanied by adequate support for research and education in the universities as well.

Question 4: What is the role of the consortium, versus the director of the national facility managed by the consortium, in setting research priorities, budget levels, personnel ceilings and salaries for the national facility?

Response: UCAR, through its Board of Trustees and its President, has the legal and fiduciary responsibility to establish goals, research priorities, budgets and personnel practices for the activities UCAR plans and operates, including the National Center for Atmospheric Research.

Major programmatic responsibility is focused in the Board's Budget and Program/Executive Committee which reviews all NCAR activities and plans and makes recommendations to the Trustees regarding budget and planning objectives and priorities. The Personnel Committee of the Board maintains detailed oversight of all NCAR salary and personnel policies and practices, and their recommendations are used by the Trustees as input into planning decisions. All budgets and annual program plans must be approved by the Board of Trustees before submission to NSF.

The Members' Representatives of UCAR conduct a community-based peer review of the quality of NCAR's research and facility programs and plans. Recommendations of the review panels have great influence on budgets and plans of the Center. This review process has been designed to meet the accountability requirements of the Members and of the NSF.

It is important to stress once again that the corporation's function is to draw the talent of the universities into the planning, review, and activities of the Center, and that in discharging their duties, the Trustees and the Members' Representatives integrate the views of the community as gleaned from many formal and informal sources.

The Director of NCAR is the executive and scientific leader of the Center, and is responsible for the scientific direction and productivity of NCAR research and facility programs. The Director is responsible for all phases of operation of NCAR, carrying out these operations following programmatic, policy and organizational guidance from the UCAR Trustees and the President, and subject to the provisions of the UCAR-NSF contract for the operation of NCAR.

The Director develops and recommends to the Corporation proposed plans, budgets, program priorities and staffing resources, and changes in policy (including salary policy and ranges) as he or she deems appropriate. The Director makes or oversees all staff appointments, subject to Board approval for certain predesignated positions; establishes such advisory mechanisms as deemed necessary and effective; ensures effective NCAR participation in reviews of NCAR programs and plans by UCAR and the sponsor; and establishes and maintains an effective system of communication, consultation, and coordination with the National Science Foundation as well as with other agencies, on operational matters related to NCAR scientific programs, facilities and administration.

Thus, while responsibility for management and operation of the Center rests fiducially, contractually, and legally with the consortium, and it is carried out by the consortium, this involves appropriate delegation of responsibility to the Director for the operation of the Center.

Question 5: (Part 1): As international participation in your research activities increases, are new problems created (for example: Obtaining permission to conduct research in the "exclusive economic zone";

political issues which could destablize the support of the program; and intellectual partnership and scientific exchange)?

Response: The conduct of atmospheric research has a long tradition of international cooperation. This tradition grows out of the decades-long arrangements among the nations for the exchange of daily meteorological data and climatological information.

UCAR and NCAR have been involved in substantial international activity for twenty years. Among the types of international activity we have participated in are: Planning and execution of international field experiments, many of them subprograms of the Global Atmospheric Research Program; participation in planning of current and future programs, such as the World Climate Program, the Global Tropospheric Chemistry Program, and the Global Change Program; U.S. solar eclipse expeditions; exchange of visitors to and from foreign countries; participation in international scientific bodies such as International Council of Scientific Unions and the International Astronomical Union; and programs carried out under bilateral agreements with India and the People's Republic of China.

The global nature of the atmosphere demands that our research be carried out in the international arena with international participation and cooperation. Thus far we have not encountered major problems in this realm, and we foresee none for the future provided no new barriers are erected that would impede cooperative projects or the exchange of scientific visitors and information.

There are sometimes minor perturbations, such as the current somewhat unsettled position of the United States about access to supercomputing services for certain foreign visitors. But they have not disturbed the solid pattern of international cooperation that has characterized atmospheric research over the past three decades.

Question 5: (Part 2): How do you prepare for sustained international program support, and what is the consortium's role versus NSF's role in this regard?

Response: UCAR has prepared for sustained participation in international programs in two ways, scientific and managerial.

The majority of the senior NCAR scientific staff have had considerable experience in international planning activities, in the execution of international field experiments, in exchange of scientific visitors, and in the development and maintenance of archives of international data. These staff members, who are UCAR employees assigned to NCAR, constitute a valuable resource for the NSF, other federal agencies, the universities and the nation in the leadership of international activities.

In addition, UCAR staff members are experts in planning and in the logistical and managerial aspects of international scientific activities in atmospheric research, astronomy and oceanography, and are almost constantly engaged by the NSF to manage, or to assist in the management of, various international field experiments, conferences and scientific exchanges, and planning enterprises. In so doing, UCAR staff have also assisted NSF in the management of foreign currencies under U.S. control. UCAR therefore serves as a management and logistics resource in international affairs for NSF.

It is our view that UCAR, a non-governmental organization skilled in international affairs, often finds it easier to perform management and logistics tasks than it might be for federal agencies, and that UCAR's participation in these activities reinforces the image of purely scientific motivation behind U.S. international scientific activities.

Question No. 5 (Part 3): How do you plan to involve additional nations in the cost sharing of our international science programs?

Response: Cost-sharing agreements with foreign governments are negotiated by the relevant U.S. government agencies as part of bilaterial, multilateral, and other agreements related to specific international activities. These negotiations are the exclusive responsibility of the federal agencies involved. When UCAR and NCAR staff members are involved (usually as part of international planning bodies, such as the International Union of Geodesy and Geophysics), it is only in an advisory capacity to the cognizant federal agency.

Question 6: Does your organization purchase insurance for reimbursement of loss, damage, or penalty (indemnification)? What is the cost of this insurance, and what level of protection is provided by the insurance you purchase? Who would pay damages not covered by the insurance or if the insurance protection levels are exceeded? Do you have recommendations on how indemnification should be addressed by the government?

Response: Under our contract with NSF, UCAR is required to provide and maintain workmen's compensation, employer's liability, comprehensive general liability (bodily injury), comprehensive automobile liability (bodily injury and property damage), comprehensive aircraft and balloon liability (bodily injury and property damage) and other insurance as NSF may specify. All insurance policies must be approved by NSF. In addition, UCAR, on its own initiative, purchases other types of insurance, which are described below.

The following sections respond to various parts of the question posed above.

a. Insurance maintained by UCAR for bodily injury or property damage. UCAR purchases the following types of insurance that provide reimbursement (subject to standard policy exclusions) for loss or damage due to bodily injury (BI) or property damage (PD):

Type of Insurance	FY 1986 Cost	Level of Protection
Auto	$ 26,000	$ 1,000,000 BI,PD
Aviation	120,000	50,000,000 BI,PD
Scientific Ballooning	30,000	100,000,000 BI,PD
Comprehensive General Liability	12,000	1,000,000 BI,PD
Umbrella	17,800	5,000,000 (Excess of Auto and Comp. Gen. Liability)
Cray Computers (not government property	18,000	Equipment value (stated in policy)
Leased Personal Property	5,000	Equipment value
TOTAL	$ 228,800	

b. Indemnification Insurance. Insurance for reimbursement of penalty (indemnification) is included in the policy on comprehensive general liability. This policy also includes a fidelity bond for employees.

UCAR maintains the following additional types of penalty (indemnification) insurance:

Type of Insurance	FY 1986 Cost	Level of Protection
Directors and Officers	$ 1,730 (see note)	$ 5,000,000
UCAR fiduciary Liability under ERISA	1,759	1,000,000
Special accident	2,903	5,000,000
TOTAL	$ 6,392 (see Note)	

NOTE: UCAR's Directors and Officers insurance covers UCAR Trustees, officers, and employees for wrongful acts performed in their respective capacities. The policy expires May 15, 1986 and the price is likely to go up, due to the rapidly shrinking supply of this type of insurance. It is also likely that employees will no longer be covered.

UCAR is now attempting to arrange for professional liability insurance, an area where there has been an explosion of lawsuits and large awards during the past several years. The most pressing need for this indemnification is to cover activities of the Terminal Doppler Weather Radar Program, a program undertaken by NCAR under sponsorship of the Federal Aviation Administration. It is not certain that UCAR can obtain sufficient insurance to cover this activity, and the cost may be prohibitive (estimates are $100,000-$500,000 for $50 million of annual coverage). If the insurance is unavailable, either NCAR will have to withdraw from the project or FAA will have to furnish its own indemnification, which it is authorized to do under law.

c. Who would pay damages not covered by the insurance or if insurance protection levels are exceeded? These would be allowable costs under UCAR's contract with NSF if they are the result of final judgments or settlements approved in writing by NSF. Under the contract, maximum allowable costs per incident are the lesser of $5 million or the amount of funds remaining unobligated or expended under the contract. Beyond this, the only recourse would be to special action by the National Science Foundation or by UCAR, which has only a small corporate reserve.

d. Do you have recommendations on how indemnification should be addressed by the government? I am not an expert in insurance matters, and therefore will not comment on what the government can or should do to alleviate the general insurance crisis that afflicts the nation. With respect to UCAR, so long as coverage is available in the marketplace at reasonable prices, insurance is preferable to indemnification. Should the cost of insurance become prohibitive or if adequate insurance should be unavailable, our Federal sponsors will have only two choices: To furnish indemnification or to see all or part of our activities shut down. In the case of NSF, we understand that this would require enabling legislation.

We take this position because UCAR is a small, nonprofit corporation with limited assets (compared to the kinds of awards that often come out of lawsuits and similar circumstances). UCAR therefore is not in a position to self-insure.

Question 7: **What effort do you make to increase the number of universities which are members of your consortium? What is being done to assure that talent in non-member universities is involved in the consortium research planning and priorities?**

Response: UCAR membership currently comprises 55 North American institutions of higher learning which grant Ph.D. degrees in the atmospheric and related sciences. UCAR started in 1959 with 14 members universities. Over the years, UCAR worked to create new atmospheric research programs in the nation's universities and helped them to achieve the breadth and quality to make them eligible for membership. Because UCAR believes that progress in atmospheric research will be promoted by broad membership in UCAR, we encourage applications for membership. Over the past five years, seven institutions have joined UCAR.

Participation in UCAR activities, including the research and facility programs of the National Center for Atmospheric Research, are open to all scientists, whether or not they are from member institutions.

The Member Institutions, which have a deep interest in and a sense of ownership and commitment to UCAR and its activities, obviously play a significant role in carrying out UCAR responsibilities, and that is appropriate. But the Corporation's commitment is to the health of the atmospheric and related sciences in the nation and world, and this commitment is realized by involving scientists wherever they reside.

Question 8: Is your contract with the National Science Foundation clear as to what the consortium manages, how and what the lab or project director manages, and what responsibilities are of the NSF and National Science Board? Please describe policies and criteria which clarify these responsibilities.

Response: The contract stipulates that UCAR has the broad responsibility for the "management, operation and maintenance of the National Center for Atmospheric Research and for the initiation, planning, and execution of its programs and activities."

This broad delegation has been the hallmark of the NSF-UCAR relationship since NCAR was established in 1960. It is clear that UCAR has the responsibility to design and propose to NSF the programs of the Center. UCAR is further assigned the responsibility to ensure that the NCAR program responds to the needs of the nation, is integrated with the interests and needs of the atmospheric science community, and is coordinated with the plans and activities of NSF.

Certain aspects of NSF oversight are spelled out in the contract. Various UCAR policies require NSF prior approval, e.g., those concerning employment, compensation, visitor appointments, and use of scientific facilities. The contract also has provisions requiring NSF approval of certain specific actions, e.g., appointment of the Director of NCAR; the Director's annual salary; reprogramming of funds above a specified level once the annual Program (operating) Plan has been approved by NSF; acceptance of non-NSF funds for support of center activities; and establishment of programs with foreign institutions. In addition, the contract includes other normal government requirements (e.g., NSF approval of various types of subcontracts).

The goal UCAR has adopted, with NSF's concurrence, is to achieve the utmost in quality and scientific productivity out of the resources that are available to NCAR and collaborating scientists and institutions. In our experience, the probability of achieving that goal is highest in an environment that provides the maximum amount of flexibility and initiative consistent with prudent management and sponsor oversight. We believe the current distribution of responsibilities is appropriate and that a swing in either direction would either damage the consortium's and the center's productivity or inappropriately limit NSF's oversight responsibilities.

The contract does not address National Science Board responsibilities.

Questions Addressed to Dr. Murino

Question 1: NCAR receives approximately one-half of total NSF budget for atmospheric science. What percent of the NCAR budget supports research conducted by NCAR scientists vs. providing facilities for university scientists? Why does NCAR have an "in-resident" scientist program?

Response: The answer to the resource allocation question comes from a careful annual post hoc analysis of all expenditures. This analysis is carried out in order to furnish management with information on the proportions of NCAR expenditures that support university research, NCAR research, joint university-NCAR research, and other non-NCAR research (such as that conducted by federal laboratories). The analysis, which is conducted by UCAR and reviewed and approved by UCAR's corporate auditors, shows the following breakdown for FY 1984. (The FY 1985 analysis is now in process.) It applies to all expenditures of NCAR, including funds from agencies other than NSF.

Total NCAR Resources Devoted to the Following in FY 1984	
University research	27 percent
Joint university-NCAR research	27 percent
NCAR research	34 percent
Other non-NCAR research	12 percent

The "Joint" category can be appropriately divided equally between NCAR and the universities. The division then is:

Support of university research	41 percent
Support of NCAR research	47 percent
Support of other non-NCAR research	12 percent

These proportions have remained constant within a few percent for the past five years. The trend has been slightly downward for NCAR and joint research and slightly upward for university research.

As I discussed in my testimony of February 25, 1986, the NCAR in-resident staff is essential to the mission of NCAR. The key problems in atmospheric research--e.g., acid rain, or the effect of carbon dioxide on the earth's climate--require the collaborative efforts of scientists, engineers, and computer experts from many subdisciplines. The most important part of NCAR's mission is to engender, lead and participate in collaborative efforts of this kind. In order for this to happen, it is essential to have a resident staff that has the scientific expertise and stature to serve as an essential nucleus for collaborative efforts and which exists in an institutional framework that allows the scientists to make long-term commitments to study the most important problems. This arrangement allows university scientists to participate on a part-time basis while continuing to honor their commitments to teaching and to their own research.

In addition, the resident staff, interacting constantly with facilities staff, ensures that the research facilities are of the highest quality, are appropriately designed, and are capable of meeting the most important needs of atmospheric research.

Question 2: UCAR manages a fleet of four NSF-owned research aircraft. What role does UCAR play in this management system? Could the research aircraft be managed similar to the university-owned ships for ocean research under the University National Ocean Laboratory System (UNOLS)? What would be the advantages or disadvantages of a UNOLS-type management system?

Response: UCAR's management of the aircraft fleet is subsumed under the responsibilities assigned to UCAR by NSF in its contract to operate NCAR. Specific responsibilities related to the aircraft fleet include:

a. Overall planning for the NCAR Research Aviation Facility.

b. Developing, in concert with the user community, the specifications and scientific justification for various types of aircraft and specialized instrumentation.

c. Acquiring and equipping the aircraft.

d. All aspects of aircraft maintenance and operation.

e. Developing and installing navigation and specialized instrumentation in the aircraft and data-processing facilities on the ground, so that the result of scientific experiments are transformed into easily used data sets.

f. Working with user scientists in the planning and execution of research projects.

g. Establishing and conducting a resource allocation system that promotes the highest scientific use of the aircraft and ensures fair treatment of all applicants for aircraft time and services. This system is conducted primarily by the NCAR Research Aviation Facility Advisory Panel, made up of leading aircraft-knowledgeable scientists from across the nation. This panel not only advises on allocations and scheduling of aircraft for various proposed experiments, but also reviews plans for the future of the NCAR Research Aviation Facility.

h. Conducting periodic reviews of the quality and scope of the activities of the NCAR Research Aviation Facility. These reviews are carried out on behalf of UCAR and NSF by panels of experienced scientists across the U.S.

It is important to note that the NCAR aircraft are the only aircraft in the nation available full-time for general use by the university atmospheric research community. The planes of NOAA and NASA are sometimes available, but this is subject to the mission requirements of the agency. Similarly, there are certain smaller aircraft that are owned and operated by individual universities, but the owner university will generally assign its own programs top priority.

UNOLS is an association dedicated to coordinating schedules for research ships of universities and other organizations whose primary funding comes from the government. It also performs other services, such as establishing standardized medical advice on all ships and advising on safety standards. Most other aspects of ship management are left to the respective operating institutions. Therefore, UNOLS should be viewed as one element in the management of the ships, rather than a full management mechanism.

In the conduct of major field experiments, there is already a good deal of coordination among NCAR, the universities, and government agencies in the use of aircraft. This is done on a project-by-project basis. Examples are many international experiments of the Global Atmospheric Research Program during the 1970's, the Cooperative Convective Precipitation Experiment conducted on the northern High Plains in 1981, and the Pre-STORM program and Genesis of Atlantic Lows Experiment conducted earlier this year. It is our view that coordination among the various agencies and universities with respect to major experiments is quite good now.

Moreover, UCAR has established an effective mechanism for the allocation of all NCAR aviation resources for use by university scientists. This mechanism is a national advisory panel before which come all requests for NCAR aircraft time. This mechanism has been tested for more than two decades. It has a reputation for fair and impartial treatment, helps to ensure the best and highest use of the NCAR aircarft fleet.

In summary, we should stress that there is a good deal of coordination already in existence with respect to the use of aircraft in large national and international programs, and that there is an effective allocation mechanism for NCAR aircraft time. There were no analogous mechanisms in place for the coordination of shipborne research activities before the establishment of UNOLS.

Without further detailed study, I cannot give a detailed analysis of the advantages and disadvantages of applying a full-fledged UNOLS schedule coordinating system to the aircraft operated by NCAR and the universities.

Question 3: Approximately one-third of the NCAR budget is allocated to scientific computing. What impact will the establishment of the NSF national computing centers and the rapidly decreasing cost of advanced computing have on NCAR's scientific computing role and future needs?

Response: As the committee recognizes, there are revolutionary changes sweeping across the national scientific computing landscape.

Some aspects of my answer to this question must be tentative. In January, UCAR established a special committee to study the current national computing scene and to recommend what capabilities and services are most needed at NCAR during the coming decade to support high scientific productivity in atmospheric research. This committee, made up of computer experts and experienced users of large computer resources from around the nation, will complete its work in the fall. Close liaison is being maintained with NSF during the process.

It is certain that atmospheric research will continue to require large amounts of supercomputing resources. For example, to understand and determine the predictability of the world climate system (which involves the oceans, the underlying land surface and the sun's radiation), requires mathematical models that contain processes that range in size from the microscopic to the global and in duration from fractions of seconds to years and centuries. To run such models fast enough to make the research practical, the largest available computers are necessary. Similarly large computing capability is necessary to handle the vast amount of data produced by satellites, radars, research aircraft, and other instruments.

For these reasons, UCAR considers supercomputing to be a critical and central requirement for NCAR and for the user community of atmospheric scientists. Access to supercomputing and associated, specialized services is essential to that community.

NCAR has for two decades pioneered in developing and providing specialized computing resources to the atmospheric sciences community. Unlike the situation in many disciplines, a whole generation of atmospheric scientists has now achieved the experience and sophistication required to use supercomputers to make significant advances in atmospheric knowledge. In order to serve atmospheric research adequately, NCAR has developed a highly specialized, advanced computing capability that provides an array of software libraries, mathematical algorithms, and large data sets tailored to the needs of the atmospheric research community. This summer NCAR will be installing a CRAY X-MP 4800 computing system similar to the capabilities being acquired by the new NSF supercomputing centers.

The NSF supercomputing centers are being developed using much of the experience that has been gained at NCAR. However, unlike the NSF centers, which will serve users from all areas of science, the NCAR center will continue to be dedicated to the atmospheric sciences and closely related sciences, which include solar physics and oceanography. Our position has been well documented; the need for continuing to dedicate high-level, specialized computing resources to atmospheric research is clear.

UCAR has strongly supported the NSF supercomputing initiative. We have provided much advice, based on our own long experience. Some of our staff members have served on the program and technical committees that planned the overall program. We have conducted a workshop to share our experiences with the directors of the new centers. Under the sponsorship of the NSF Office of Advanced Scientific Computing, we have begun an experiment in satellite communication for computing, which we expect to serve as a prototype for communications with the new centers.

We expect that the existence of the new centers, plus the growing capabilities of very large mainframe computers, will bring many changes to the way in which large-scale computing is done, particularly in areas of science where the potential of supercomputers is not yet realized.

Similarly, the growing capabilities of computers on university campuses (through the acquisition of "super-minicomputers" such as the DEC VAX) gives university scientists much more capability either right at their desks, through departmental computers, or via internal university computing networks. As a result, the mission of the NCAR computing center may become more focused on development and running those large models and treating those large data sets that cannot be handled on the university campus.

It is still too early to tell what the impact on NCAR will be as a result of the establishment of the NSF supercomputer centers. They are new, and we will watch their evolution with interest.

Among the potential benefits to NCAR that could accrue from NSF's new supercomputer program are the following:

-- The communications network which NSF establishes could help to provide UCAR universities far more rapid and broadband access to NCAR computers.

-- Some computing tasks that require speed but do not require the specialized capabilities or NCAR (e.g., large data sets that are computer-optimized for atmospheric or ocean science programs) might migrate to the new centers, and thereby increase the total capability available to our fields of science.

-- NSF's influence on the computer industry may lead to the more rapid advent of next-generation machines closely tailored to the needs of large-scale scientific computing, and the results may bring more economical computing than would otherwise be the case.

-- There may be an increase in the production of computer software relevant to atmospheric research that could be shared among many centers.

There could also be disbenefits to the atmospheric sciences and to NCAR's capability to serve its users. However, we plan to work with NSF to ensure that adequate supercomputer resources, which are as central to our area of science as any other, continue to be available to atmospheric researchers. UCAR believes that atmospheric science can best be served by an NCAR supercomputing center dedicated to its special requirements.

Question 4: What are the overwhelming values of consortia-managed national scientific research facilities versus an NSF-managed facility?

Response: With respect to atmospheric research, it is important to keep in mind the mission of the National Center for Atmospheric Research. Its mission is to draw the nation's scientific talent, particularly in the universities, into concerted attacks on atmospheric problems of concern to the nation. Since the center is operated by a consortium of nearly all U.S. universities with graduate programs in atmospheric science, the university community is therefore the author not only of the NCAR program, but also of collaborative national research efforts the nation needs.

The close involvement of the university community in the identification, planning and execution of atmospheric research programs is essential to continued rapid progress focused on the most important problems in atmospheric research. Through this close association, scientific integrity and high standards are promoted, and communications and collaboration between the center and the universities are fostered. The involvement of the university community helps to generate broad constituency support for NCAR, rather than the feeling of competition that could exists if they were not so involved in setting NCAR priorities.

The university atmospheric sciences community has effectively discharged its responsibility for these tasks through its involvement in UCAR. As stated in my testimony, the university community contributes about 3,000 person-days per year of on-site consultation, without compensation, and an equal amount of time contributed in preliminary study and analysis of issues and in follow-up actions.

The universities contribute this level of effort because they see NCAR as "their" center and that they are responsible for management of the center, for setting its priorities, for participating in the design of its programs, and for ensuring that NCAR serves the national interest in the wisest way. They recognize that their degree of involvement is much more effective than it would be were they merely advisors to a federal agency.

Providing the mechanism whereby the universities can marshal and focus their capabilities is the "overwhelming value" of this university-based consortium as operator of the National Center. It is much more favorably placed to do this than a government agency would be. In assigning this responsibility to the university community, the National Science Foundation has wisely recognized this fact, and its judgment is borne out by the success of the National Center in achieving international recognition as the world's leading atmospheric research institution.

In addition, UCAR provides a prestigious, legally responsible Board of Trustees for governing the affairs of the corporation, including the operation of NCAR. UCAR provides efficient, highly responsible financial and administrative management; every annual audit of UCAR has resulted in a "clean" audit report. Finally, UCAR, as a private non-profit corporation, has been in a position to pioneer in the use of its tax-exempt status to finance the acquisition of equipment and has used its purchasing power to pool university equipment and data needs and to obtain quantity price discounts. Both of these activities has resulted in savings to the government.

Mr. **Walgren**. Thank you very much, Dr. Murino. I appreciate that.

Dr. Baker?

Dr. **Baker**. Mr. Chairman, and members of the subcommittee, thank you very much for the opportunity to meet with you today to discuss the impact of the proposed 1987 budget for the National Science Foundation.

The oceanographic research community has had a long and mutually beneficial relation with the National Science Foundation, and we are looking to continue this relation with the support proposed in the new budget.

We also want to state at the outset our gratitude for the continuing interest and support of the subcommittee and the full committee in the ocean programs of the National Science Foundation, and particularly the ocean drilling program.

I am the president of Joint Oceanographic Institutions, Inc., a nonprofit corporation formed by 10 universities and oceanographic institutions to bring the collective capability of individual institutions to bear on large oceanographic research projects.

The corporation operates as a coordinating body and systems manager for the member institutions. It subcontracts operating activities to its member institutions and other academic and industrial organizations.

We began operations in 1978. Today, we are responsible for two major National Science Foundation activities, and we also have funding from NASA for coordination of satellite oceanography.

Our major National Science Foundation activity is the ocean drilling program, a 10-year activity that involves a total expenditure in fiscal year 1986 through our organization of about $32.5 million, of which about $20 million comes from the United States and $12.5 million comes from five foreign countries: Canada, Federal Republic of Germany, France, Japan, and the United Kingdom.

We are also involved in supporting U.S. science activities to the tune of about $3.6 million.

The aim of the ocean drilling program is to better understand the Earth. In the program the scientists use cores collected by a drill ship and other data collected by the latest technology to document and understand the properties of the Earth's crust.

Earth scientists are particularly interested in ocean drilling because the oceanic crusts offer layers of sediment that are undisturbed by wind and rain and a basement structure that is far closer to the surface than under continents.

Moreover, ocean drilling opens the way to the study of geological processes anywhere on Earth.

The scientific direction for the program is provided by an international group of scientists under the name of Joint Oceanographic Institutions for Deep Earth Sampling, JOIDES.

Science operations are managed for us by Texas A&M University, which is responsible for ship operations, publications, and core samples. Downhole measurements or logging is the responsibility of Lamont-Doherty Geological Observatory of Columbia University.

The central facility for the program is an advanced ocean drilling ship, the *Joides Resolution*, jointly owned by SEDCO and BP. The ship is one of a kind, carrying 30,000 feet of drill string, and able to drill in depths of up to 27,000 feet almost everywhere in the ocean, and with laboratory facilities unmatched on land or sea. With satellite navigation and precise acoustical location techniques, the ship drills and collects cores of sediment and basement rock from the Earth's crust beneath the sea.

From this information earth scientists are able to reconstruct the history of ocean basins, study the rearrangement of continents, the structure of the Earth's interior, the evolution of life in the oceans, and the history of climate change.

Thus, we are led to a more complete understanding of Planet Earth, past, present, and future.

The understanding of the overall system also allows us to identify regions of potential resource development, an issue of important societal interest.

The ocean drilling program is not, in itself, aimed at finding resources, but the understanding of Earth processes that is gained through such a basic scientific research program will inevitably be one piece of the information required for such resource discovery and exploitation.

This program builds on a long and successful history of ocean drilling carried out over the past 17 years. The theory of the dynamic and changing character of the Earth leading to plate tectonics was confirmed. Now we look forward to exploring new regions and delineating the processes that underlie the dynamic Earth as we begin the new program with a new drill ship.

In terms of management, the ocean drilling program is a unique formal international partnership of scientists and governments that has proved to be responsive and decisive. The partnership today consists of a scientific advisory arm with representatives from 10 institutions and 5 non-U.S. institutions and a management arm, Joint Oceanographic Institutions, Inc.

The principal committees are an executive committee made up of senior managers of member institutions and a planning committee made up of senior working scientists who represent their own institutions.

The planning committee is the focal point for the scientific planning for the program and the key to the scientific success. The committee screens recommendations, selects drilling targets. The science operator, Texas A&M, is responsible, in turn, for producing the detailed ship tracks and the final scientific rosters.

On each leg, there are about 25 scientists and 25 technicians in addition to the ship's crew and the drilling crew.

International participation is a key to the program. It makes it scientifically broad and economically cost-effective. ODP operates as an international and multilateral program. Each non-U.S. member agrees in principle to support the program throughout its planned 10-year span.

The current contribution base is $2.5 million per year. In return for that contribution, each member is guaranteed a seat on each committee, panel, and working group, representatives on the teams for the cruise legs, one cochief scientist per year, and full access to all data and samples.

In addition to the yearly contribution, each partner nation makes other important contributions. Non-U.S. scientists are part of our operating teams. Materials and equipment for the shipboard operation have been purchased from those countries that can provide the best value. Each participating country also supports a research program that is complementary to the drilling program.

The only formal international coordinating mechanism is the ODP Council, a governmental consultative body established under bilateral agreements and chaired by the United States. It periodically reviews the general progress of the program and discusses financial plans and other management issues.

The overall scheme has worked well for this program and may serve as a model for other large programs that involve large facilities and many international participants.

Let me speak now about the impact of the 1987 budget on ocean drilling.

The scientific priorities of ocean drilling today are to continue the global reconnaissance, to study in detail areas of major activity such as mid-ocean ridges, to study climatic variations, and to look at the mechanisms of evolution.

Many of the scientific objectives can be met only with new technology. Therefore, we are looking to drill into bare rock at mid-ocean ridges, hydrothermal areas, high latitudes. We want to drill deeper into areas where high pressure may be encountered. This will require the use of a riser or outer cylinder that provides for circulation and helps to protect against blowout or venting.

Not all of these scientific and technical objectives can be met at once, or even a 10-year period. Yet we know that as we look deeper into the Earth's crusts, we gain a more fundamental understanding about the Earth and how it works.

I am pleased to report that even though we have now completed barely 1 year of drilling with the new ship, we have already met several of our technical objectives.

We have drilled in high latitudes to get new data on ancient climates, and we have drilled for the first time on bare rock in the mid-Atlantic ridge, bringing back the first samples from hydrothermal circulation regions.

The fiscal year 1987 budget is crucial to the continuation of these activities. The budget provides for a total of $45 million for the ocean drilling program. Of this total, NSF expects to receive $15 million in contributions from foreign partners. This makes the U.S. total about $30 million. The growth is made up of an increase in non-U.S. funds of $2.5 million, anticipating a sixth foreign partner, and an increase in U.S. funds of about $1.2 million.

We strongly support the budget. It is consistent with the ongoing development of a healthy program of science and engineering. The increase will be used to cover a small increase in the cost of ship operations, modest engineering development program that will allow us to drill in targets that have special scientific interest, such as high temperature regions, and will allow for a greater support of U.S. science.

These are all major objectives and must be supported if we are to meet the goals as originally set out.

Let me conclude with some words about the future.

Geoscientists are fond of pointing out that it is the Earth's own inner life—the convective processes deep within its interior—that have determined its history and our own.

Today, thanks to the results from ocean drilling and logging, seismic, gravity, magnetic, heat flow, and a variety of other techniques, we have an emerging view of a dynamic, changing Earth.

Plate tectonics is a surface manifestation of the Earth's inner life: The continual recycling of the Earth's surface materials deep into the interior, and their reappearance along the mid-ocean ridges and in volcanoes leads to the distribution of material at the surface and, in fact, leads to the persistence of the benign chemical environment that is important for life.

With continued ocean drilling and with expanded programs of continental drilling and global seismic networks, we hope to describe and achieve a better understanding of the Earth and its processes.

In fact, we have discovered that it is possible to learn about the structure of the universe from deep ocean drilling. Recent studies have suggested that the gravitational constant may, in fact, vary over distances as short as a few hundred meters. Such a variation would have profound implications for the physics of the universe.

It should be possible to use measurements of gravitational acceleration in boreholes in the deep ocean to estimate the dependence on length. That is, from studies of the Earth's structure to the origin of life, to the physics of the universe, we see that direct sampling of the Earth, as exemplified by ocean drilling, is the key to understanding the world around us.

The scientific community has had a long and mutually beneficial relation with the National Science Foundation, and we are looking forward to continuing this relation for the lifetime of the ocean drilling program.

Thank you.

[The prepared statement of Dr. Baker and answers supplied to questions for the record follow:]

PREPARED STATEMENT OF DR. D. JAMES BAKER

INTRODUCTION

Mr. Chairman and members of the subcommittee:

Thank you very much for the opportunity to meet with you today to discuss the impact of the proposed FY 1987 budget for the National Science Foundation on the operation, maintenance, and upgrade of large-scale national facilities, and on the adequacy of resources to support maximum utilization of these facilities for research.

The oceanographic research community has had a long and mutually beneficial relation with the National Science Foundation, and we are looking to continue this relation with the support proposed in the new budget. We also want to state at the outset our gratitude for the continuing interest and support of this Subcommittee and the full Committee in the ocean programs of the National Science Foundation and ocean drilling in particular.

JOINT OCEANOGRAPHIC INSTITUTIONS

I appear before you today as the President of Joint Oceanographic Institutions Incorporated, a non-profit corporation formed by ten universities and oceanographic institutions to bring the collective capability of individual insitutions to bear on large oceanographic research projects. A list of the member oceanographic institutions of JOI Inc. and its Board of Governors is appended.

The Corporation operates as a coordinating body and systems manager for the member institutions. It subcontracts operating activities to its member institutions and other academic and industrial organizations. JOI began operations in 1978 as a nonprofit corporation designed to plan and manage the geological and geophysical explorations proposed by U.S. institutions associated with deep ocean drilling, and to foster other oceanographic research. Today, JOI is responsible for three major NSF-funded projects, and also has funding from NASA for coordination of ocean research.

The major NSF activities are the following:

- The scientific planning and operations management for the ten-year international Ocean Drilling Program (ODP), an operation that involves a total expenditure of about $32.5 Million through JOI in FY 1986, of which about $20 Million comes from the U.S. and the remainder from five foreign partners (Canada, Federal Republic of Germany, France, Japan, and the United Kingdom);

- Support of the U.S. scientific community's participation in the Ocean Drilling Program in order to place the U.S. activities on a par with the infrastructure in place in the ODP partner countries. This activity is about $3.6 Million in FY 1986.

In addition to management of these projects, JOI supports planning for oceanography from space with particular reference to missions and data management, a NASA-funded project. This is a five-year effort, at a funding level of about $500,000 per year. Finally, JOI is supporting planning groups for studies of a global ocean flux study, a magnetic field satellite, operational satellite data management, and relection profiling facilities. These studies are supported by NSF and NASA.

JOI stands ready at all times to assist its member institutions, the oceanographic community, and the Federal Government in other endeavors that require a focus for collective efforts in ocean science.

THE OCEAN DRILLING PROGRAM

Our major activity is the management of the Ocean Drilling Program, an international cooperative venture to explore our planet's last frontier -- Earth's structure and history as it is revealed beneath the ocean's basins.

The scientific direction for the program is provided by an international group of scientists named Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). Science operations are managed for JOI by Texas A&M University, which is responsible for ship operations, publication of results, and storage of the core samples. Downhole measurements, or logging, is the responsibility of Lamont-Doherty Geological Observatory.

The central and major facility is an advanced ocean drilling ship, the JOIDES Resolution (officially the SEDCO/BP 471). The ship is one of a kind, carrying 30,000 feet of drill string and able to drill in depths up to 27,000 feet, and with laboratory facilities unmatched on land or sea. With satellite navigation and precise acoustic location techniques, the ship drills and collects cores of sediment and basement rock from the earth's crust beneath the sea.

The aim of the ocean drilling program is to better understand the earth. In the program, scientists use cores collected by the drillship and other data collected by the latest technology to document and understand the properties of the earth's crust. These data are then synthesized with other information to yield new insights into earth processes.

Earth scientists are particularly interested in ocean drilling because the oceanic crust offers layers of sediment that are undisturbed by wind and rain, and a basement structure that is far closer to the surface than under continents. Moreover, ocean drilling opens the way to study of geological processes anywhere on earth: mid-ocean ridges, deep-ocean trenches, and tectonically active areas around the ocean margins are all accessible.

From this information, earth scientists are able to reconstruct the history of the ocean basins and their development, the rearrangement of continents, the structure of the earth's interior, the evolution of life in the oceans, and the history of worldwide climatic change.. Thus we are led to a more complete understanding of planet Earth -- her past, present, and future.

The understanding of the overall system also allows us to identify regions of potential resource development, an issue of general societal interest. The Ocean Drilling Program is not in itself aimed at finding resources, but the understanding of earth processes that is gained through such a basic scientific research program will inevitably be one piece of the information required for such resource discovery and exploitation.

The new program builds on a long and successful history of ocean drilling carried out over the past 17 years. Among the previous discoveries was the fact that the sea floor is young in geologic time, and that it spreads from the mid-ocean ridges. The theory of the dynamic and changing character of the earth leading to plate tectonics was confirmed. Now we look forward to exploring new regions and delineating the processes that underly the dynamic earth as we begin the new program with an enhanced capability drillship. A brief summary of the program operation today and of the history of the program is appended.

PROGRAM MANAGEMENT

In terms of management, the Ocean Drilling Program is a unique formal international partnership of scientists and governments that is responsive and decisive. The partnership today consists of a scientific advisory body, JOIDES, with representatives from 10 U.S. institutions and 5 formal partners of non-U.S. institutions, and a management arm, Joint Oceanographic Insitutions Incorporated. A management chart is appended.

The terms of reference of JOIDES define members as representatives of oceanographic and marine research institutions or other organizations which have a major interest in the study of the sea floor and an adequate capability in terms of scientific manpower and facilities to carry out such studies.

The principal instruments of JOIDES are an Executive Committee (EXCOM) and a Planning Committee (PCOM). EXCOM, which provides overall management and policy guidance, is comprised of senior managers of member institutions. PCOM members are senior working scientists, named to represent their national or institutional research community.

PCOM is the focal point for all scientific planning for the ODP, and is key to the scientific success of the program. It has a network of panels and working groups which screen drilling proposals, evaluate instrumentation and measurement techniques, and assess geophysical survey data and other safety and siting information. PCOM screens the recommendations of these panels and committees to select drilling targets and to specify the major scientific objectives of each leg. The science operator is responsible in turn for producing the detailed ship's tracks, actual drilling schedules, and final scientific rosters. On each leg there are about 25 scientists and 25 technicians in addition to the ship's crew and the drilling crew.

Staff support for the JOIDES Executive and Planning Committees is provided by the JOIDES Office. The Office rotates every two years among the 10 U.S. institutions with the exception of the institutions that are major subcontractors for the program. The Office also publishes the JOIDES Journal, which serves as a means of communication among the JOIDES committees and advisory panels, the National Science Foundation, and interested earth scientists.

INTERNATIONAL PARTICIPATION

International participation makes the Ocean Drilling Program scientifically broad and economically cost-effective. ODP operates as an international and multi-lateral program, but its formal structure consists of a series of bilateral agreements between the National Science Foundation and its counterpart agency in each participating country.

Each non-U.S. member agrees in principal to support the program throughout its planned 10 year span; the current contribution base is $2.5 Million per year. In return for its contribution, each member is guaranteed a seat on each committee, panel, and working group of JOIDES, 2 representatives on the scientific team for each cruise leg, 1 co-chief scientist per year, and full access to all data, samples, technical plans and specifications for equipment and techniques developed by the program and copies of publications.

In addition to the yearly contribution, each partner nation makes other important contributions to the program. Non-U.S. scientists are part of the operations team at Texas A&M, materials and equipment for the shipboard operation have been purchased from those countries that can provide the best value, and there is a designated position for a non-U.S. scientist at the JOIDES office.

Each participating country also supports a basic research program in geology and geophysics that is complementary to and provides support for scientists associated with the program.

These basic research programs are a major contribution to the development of specific proposals for drilling sites. In the case of the U.S., NSF provides the U.S. contribution to the joint program, currently about $20 Million per year, and also funds the separate U.S. science program for ODP. The latter is handled through peer-reviewed research proposals and through JOI Inc.

The only formal international coordinating mechanism established under the bilateral agreements is the ODP Council, a governmental consultative body, chaired by the U.S., which periodicallly reviews the general progress of the program and discusses financial plans and other management issues. The overall scheme has worked well for this program, and may serve as a model for other large programs that involve large facilities and many international participants.

IMPACT OF THE FY 1987 BUDGET ON OCEAN DRILLING

The scientific priorities of ocean drilling today are to continue the global reconnaisance of geological and geophysical structures in order to provide a global description of the earth, to study in detail the areas of major activity such as mid-ocean ridges and the associated hydrothermal circulations and metal deposits, to study climatic variations such as sea level changes, ocean circulation changes, and the effects of orbital variations on climate, and to study processes and mechanisms of evolution from the biological records in the cores.

Many of the scientific objectives can be met only with new technology. Thus the program has identified technical goals, which include the ability to drill into bare rock at mid-ocean ridge sites, to drill in high temperature and corrosive regions typical of hydrothermal areas, and the ability to core in high latitudes by withstanding high seas and wind. We want to be able to drill deeper, and we want to be able to drill in areas where high pressure may be encountered. This will require the use of a "riser" or outer cylinder that protects against blowout or venting of the overpressure zone. We are also developing new tools for measurements in the hole (logging) after the core is removed. Such measurements allow us to probe the geological, physical, and chemical properties of the rocks surrounding the hole, and are essential to the program.

Not all of these scientific and technical objectives can be met at once, or even over a ten-year period. Yet we know that as we look deeper into the earth's crust, we gain a more fundamental understanding about the earth and how it works. I am pleased to report that even though we have now completed barely one year of drilling with the new ship, we have already met several of our technical objectives -- we have drilled in high latitudes in the Labrador Sea for new data on ancient climates, and we have drilled for the first time on bare rock on the mid-Atlantic ridge, bringing back the first drill samples from hydrothermal circulation regions.

The FY 1987 budget is crucial to the continuation of these activities. The FY 1987 NSF budget provides for a total of $45,050,000 for the Ocean Drilling Program. Of this total, NSF expects to receive $15,000,000 in contributions from foreign partners; this makes the U.S. total $30,050,000. The growth is made up of an increase in non-U.S. funds of $2,500,000, anticipating a sixth partner, and an increase in U.S. funds of $1,200,000 over FY 1986.

We strongly support this budget. It is consistent with the on-going development of a healthy program of science and engineering. The increase will be used to cover a small increase in costs of ship operations, a modest engineering development program which will allow us to drill in targets that have special scientific interest, such as high temperature regions, and will allow the development of better tools for downhole logging, and increased support for U.S. science. These are major objectives of the program, and must be supported if we are to meet the goals as originally set out.

A LOOK TO THE FUTURE

Geoscientists are fond of pointing out that it is Earth's own inner life -- the convective processes deep within its interior -- that have determined its history and our own.

Today, thanks to the results from ocean drilling and logging, seismic, gravity, magnetic, heat flow, and a variety of other techniques, we have an emerging view of a dynamic, changing earth. Plate tectonics is a surface manifestation of the earth's inner life: the continual recycling of Earth's surface materials deep into the interior, and their reappearance along the mid-ocean ridges and in volcanoes leads to the distribution of material at the surface. With continued ocean drilling, and with expanded programs of continental drilling and global seismic networks, we hope to describe and achieve a deeper understanding of the earth and its processes.

New directions in ocean drilling include the use of risers for drilling in geologically active areas, the use of holes as natural laboratories for broad studies of geology and geophysics, and the integration of ocean drilling with other sampling techniques like continental drilling and global seismic surveys.

Such studies must also include chemistry and biology as integral parts because life itself is affected by plate tectonics. Organic carbon is locked up in ocean sediments, thus freeing oxygen for life. But oxygen must not accumulate without limit in the atmosphere, or it would reach poisonous concentrations. Moreover, if organic material continued to accumulate in deep-sea sediments, all the nutrients released by weathering would eventually return to insoluble forms, and Earth's plants would starve. If limestone sediments continued to accumulate in the ocean without a compensating inflow of carbon dioxide from the deep-sea ridges and other volcanic eruptions, then the concentration of atmospheric carbon dioxide could become so low that photosynthesis would become impossible.

Thus the tectonic renewal that keeps the sea floor young appears to be essential to the persistence of the benign chemical environment that has allowed life to exist and evolve in all its luxuriant complexity and diversity for over three billion years.

Given the multi-discipline interest and importance, it is clear that a global study of the earth -- geophysics, geology, chemistry, and biology -- will not only tell us about the earth but also about the nature and essence of life itself. Ocean Drilling will be one essential part of that overall study, and we are looking forward to the continued successes and new ideas generated by the program.

Finally, we note that ocean drilling provides a context for studies of even larger significance than Earth itself. The universal constant of gravitation is a fundamental parameter for understanding the structure of the universe. Recent studies have suggested that the "constant" may in fact vary over distances as short as a few hundred meters. Such a variation would have profound implications for the physics of the universe. It has recently been suggested that it should be possible to use measurements of gravitational acceleration in boreholes in the Earth's crust to estimate the dependence on length. The measurements would be most effective in boreholes in the deep sea, where inhomogeneity and uncertainty about the density of the surrounding material are relatively well known.

Thus from studies of Earth's structure to the origin of life to the physics of the universe, we see that direct sampling of teh earth, as exemplified by ocean drilling, is a key to understanding the world around us. The scientific community has had a long and mutually benefial relation with the National Science Foundation, and we are looking forward to continuing this relation for the lifetime of the Ocean Drilling Program.

THE ROLE OF JOI IN LARGE PROGRAMS

It is clear that new multidiscipline programs to understand the earth will necessarily involve large facilities, whether they be drillships, seismic networks, or even satellites. Thus it is necessary that we have a mechanism for involving scientists from many disciplines in developing a broad consensus for the scientific direction of the programs. At the same time we need a mechanism for management of the facilities.

In ocean sciences, JOI plays a key role in developing that consensus. Our structure enables us to bring together groups of scientists and engineers in advisory committees and working groups, and to develop plans that can represent such a consensus. We have sponsored conferences, workshops, and reports on a variety of subjects including the future of ocean drilling, global studies of physical, chemical, and biological oceanography, and on the use of new techniques for geophysics. We have brought together the ocean community to develop plans for oceanography from space, including the important element of data management and data dissemination.

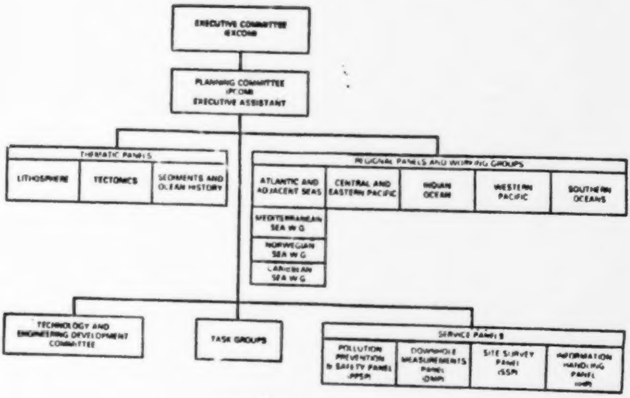
Looking at management, it is important to note that the oceanographic community has a long and successful history of facility operation by individual institutions. Many institutions operate large research vessels, and the drilling program itself has operated first through the Scripps Institution of Oceanography and now through Texas A&M University. We believe that this is a strength for management because it saves capital costs for the Federal Government, and it allows the community to have close and interactive control over the facility through a management organization like JOI. In this mode, JOI subcontracts all operations to individual institutions, while providing general management oversight as the prime contractor on programs.

JOI provides for the ocean community an effective management team. We have strong staff capabilities in contracting, finance, and general management, capabilities that are consistent with the needs of the ocean community. We have worked well, we believe, to complement the program management efforts at the National Science Foundation, and we look forward to continuing our efforts in the Ocean Drilling Program and other new programs.

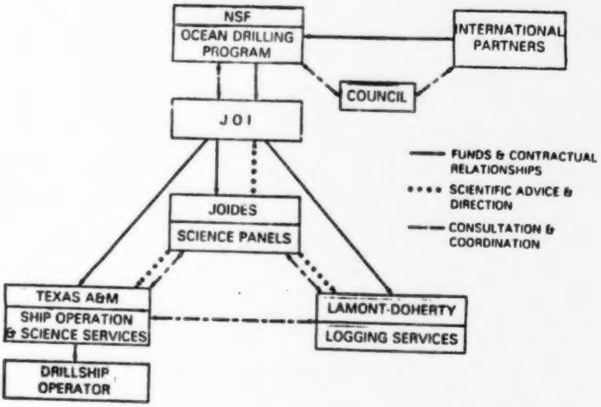
Thank you for the opportunity to present our programs to the Subcommittee.

ADDENDUM 1. Program Management

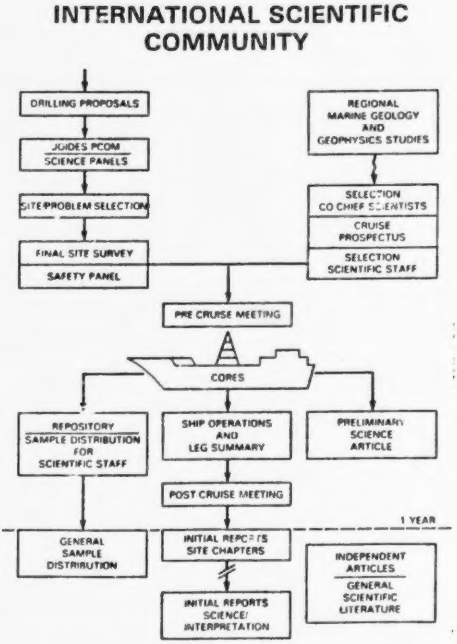
JOIDES ORGANIZATION


EXECUTIVE COMMITTEE (EXCOM)
PLANNING COMMITTEE (PCOM) EXECUTIVE ASSISTANT
THEMATIC PANELS
LITHOSPHERE
TECTONICS
SEDIMENTS AND OCEAN HISTORY
REGIONAL PANELS AND WORKING GROUPS
ATLANTIC AND ADJACENT SEAS
CENTRAL AND EASTERN PACIFIC
INDIAN OCEAN
WESTERN PACIFIC
SOUTHERN OCEANS
MEDITERRANEAN SEA W G
NORWEGIAN SEA W G
CARIBBEAN SEA W G
TECHNOLOGY AND ENGINEERING DEVELOPMENT COMMITTEE
TASK GROUPS
SERVICE PANELS
POLLUTION PREVENTION & SAFETY PANEL (PPSP)
DOWNHOLE MEASUREMENTS PANEL (DMP)
SITE SURVEY PANEL (SSP)
INFORMATION HANDLING PANEL (IHP)

OCEAN DRILLING PROGRAM MANAGEMENT PLAN



ADDENDUM 2. Program participation


INTERNATIONAL SCIENTIFIC COMMUNITY
DRILLING PROPOSALS
JOIDES PCOM
SCIENCE PANELS
SITE/PROBLEM SELECTION
FINAL SITE SURVEY
SAFETY PANEL
REGIONAL MARINE GEOLOGY AND GEOPHYSICS STUDIES
SELECTION CO CHIEF SCIENTISTS
CRUISE PROSPECTUS
SELECTION SCIENTIFIC STAFF
PRE CRUISE MEETING
CORES
REPOSITORY
SAMPLE DISTRIBUTION FOR SCIENTIFIC STAFF
SHIP OPERATIONS AND LEG SUMMARY
PRELIMINARY SCIENCE ARTICLE
POST CRUISE MEETING
1 YEAR
GENERAL SAMPLE DISTRIBUTION
INITIAL REPORTS SITE CHAPTERS
INITIAL REPORTS SCIENCE/ INTERPRETATION
INDEPENDENT ARTICLES
GENERAL SCIENTIFIC LITERATURE

ADDENDUM 3.

THE PROGRAM TODAY

The Ocean Drilling program has four major parts, all of which are critical to its success: program planning, management and operation of the facilities, distribution and use of data by a worldwide scientific community, and funding by an international partnership of nations.

Program planning is carried out by an international partnership, the Joint Oceanographic Institutions for Deep Earth Sampling, JOIDES. JOIDES is made up of the participating institutions, and is divided into committees and panels for review and approval of plans and proposals for the use of the facilities. The JOIDES plans are set into operation by the science operator, Texas A&M University, who is responsible for operations aboard the drillship, certain shore-based activities, publication of results, and core curation. Lamont-Doherty Geological Observatory is responsible for measurements in the boreholes, or logging.

The program is currently funded by the U.S. National Science Foundation, Canada, Federal Republic of Germany, France, Japan, and the United Kingdom. Management oversight for the program is provided by Joint Oceanographic Institutions Incorporated, a U.S. non-profit consortium of oceanographic institutions that serves as prime contractor.

Any scientist or group of scientists are free to submit a proposal for drilling and associated measurements. The proposals are reviewed and prioritized by one of more of the JOIDES advisory panels, and then considered for inclusion in the schedule. Ideas thus become part of the drilling program either by evolving into a mature, specific proposal, or by incorporation into an existing proposal with multiple objectives. It generally takes about three years for an idea to go from the preliminary review stage to actual drilling on site.

Included in the several stages of the review process are safety reviews, designed to minimize the possible release of hydrocarbons from subsurface reservoirs by judicious drill-site selection. In addition, safety problems may arise in drilling in hot hydrothermal systems. Such risks can be identified and minimized by careful planning and proper site surveys.

Site surveys are an important part of the program, because they allow us to set the geophysical context for the drilling. surveys include, but are not limited to, single and multichannel seismic measurements using air and water gun sound sources, side-scan sonar, SEABEAM bathymetry, piston cores, magnetics and gravity, photography, and heat flow. Clearly, the site surveys must be carried out early in the planning process.

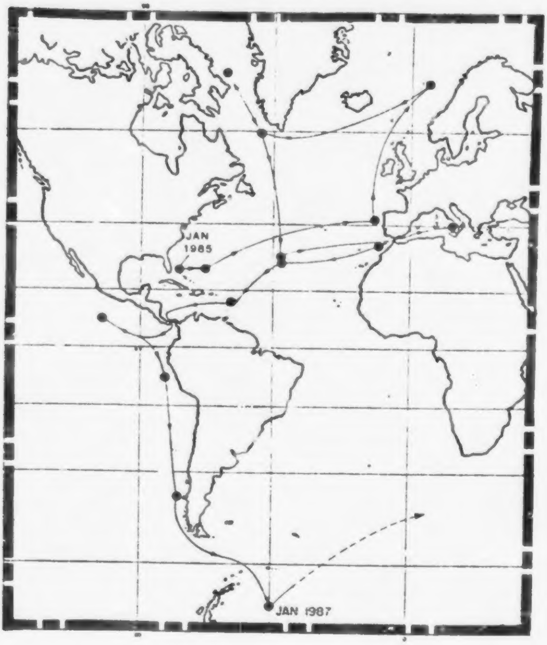
In actual operation, the drillship is at sea for eight weeks at a time. Scientists from the international community participate in these scientific cruises, or "legs" in oceanographic parlance. The location of the legs is determined by the JOIDES Planning Committee, which is responsible for setting the scientific direction of the program and for detailed planning of specific legs. The plans for 1985 - 1987 are shown in the Figure.

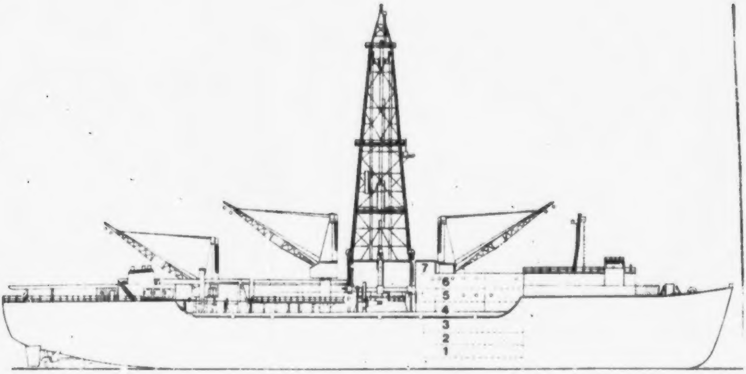
The major facility for the Ocean Drilling Program is a one-of-a-kind drillship, the *JOIDES Resolution*, that carries laboratories and equipment unmatched on land or sea. The name of the ship, an informal title, comes from the international scientfic partnership that directs the program and from the flagship of Captain Cook's second voyage to the Pacific Ocean in the late 18th century. The ship, registered as SEDCO/BP 471 after its owners and its length in feet, is 70 feet wide, and has a displacement of 16,595 long tons. Her derrick towers 200 feet above the waterline, and a computer-controlled dynamic positioning system stabilizes the ship over a specific location while drilling in water depths up to 27,000 feet. The drilling system retrieves cores from beneath the sea floor with a derrick and drawworks that can handle 30,000 feet of drill pipe.

At the center of this floating laboratory is a seven-story laboratory stack. This "lab stack" provides space and equipment for the shipboard scientific crew including laboratories for sedimentology, paleontology, petrology, paleomagnetics, and physical properties. Computer, eletronics, word processing, and photographic facilities lend technical support. A marine geophysics laboratory produces digital, single-channel seismic reflection profiles while the ship is underway. More than 12,000 square feet of space distributed throughout the ship is devoted to scientific laboratories and equipment. The ship sails with a scientific and technical crew of 50 and a ship's crew of 65.

The logging program is a major part of the overall operation. The program provides a full suite of geochemical and geophysical services for every hole deeper than 400 m. For each such hole, there are lowerings of basic oil-industry tools: nuclear, sonic, and electrical. In addition, a borehole televiewer is available for imaging the wellbore wall, and 12-channel logging tool provides accurate velocity and elastic property measurements as well as sonic waveforms for spectral analysis of energy propagation near the wellbore, and a vertical seismic profiler records reflectors from below the total depth of the hole. Temperature and flow-rate tools are available, as is a passive-mode water sampler.

SHIPTRACK JAN. 1985 - JAN. 1987





Ship's Schematic

Deck 6
- Core Receiving
- Physical Properties Lab
- Paleomagnetics Lab
- Core Splitting
- Core Description and Sampling
- Photo Station

Deck 5
- Paleontology Lab
- Paleo Prep Lab
- Scanning Electron Microscope Lab
- Chemistry Lab
- Thin Section Lab
- Petrology Lab
- X-Ray Lab

Deck 4
- Computers
- Computer User Room
- Science Lounge
- Yeoperson's Office
- Co-Chief Scientists' Office

Deck 3
- Electronics Shop
- Photo Darkroom
- Photo Finish Room

Deck 2
- Refrigerated Core Storage
- Cold Storage
- Second-Look Lab

Deck 1
- Refrigerated Core Storage
- Freezer

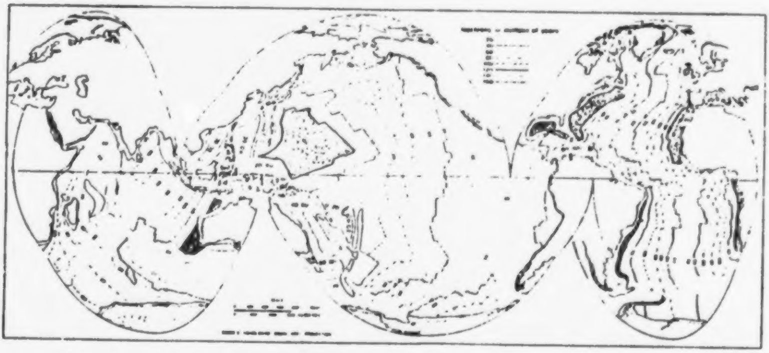
Deck 7
- Downhole Measurements

Poop Deck
- Underway Geophysics Lab

Main Deck
- Library

Texas A&M University serves as science operator for the Ocean Drilling Program. In this capacity, they operate and staff the drillship and retrieve cores from JOIDES-designated sites from around the world. The science operator also ensures that adequate scientific analyses are performed on the cores by maintaining the shipboard scientific laboratories and by providing logistical and technical support for shipboard scientific teams. On shore, Texas A&M manages scientific activities after each leg, is curator for the cores and distributes samples, and coordinates the editing and publishing of the scientific results. Lamont-Doherty Geological Observatory of Columbia University manages the ship's logging operations, which includes processing the data and assistance to scientists in data analysis.

Core samples from ocean drilling are stored for future investigation at three sites: DSDP Pacific and Indian Ocean cores at the Scripps Institution of Oceanography, DSDP and ODP Atlantic cores at Lamont-Doherty, and ODP Pacific and Indian Ocean cores at Texas A&M.



Schematic crustal age map. Ages based on data from magnetic anomalies (Berger and Winterer, 1974). Most of the pre-140 m.y. section has been subducted, but isolated areas are available for drilling in the western Pacific, eastern Indian, and north Atlantic oceans.

ADDENDUM 4.

A BRIEF HISTORY

In general, earth history is better preserved in layers of sediment on the ocean floor than on land, where mountain-building twists the records and wind and water erase them. As earth scientists collected data with new techniques and began to develop new concepts about large-scale processes in the late 1940s and 1950s, it became clear that more samples were needed beneath the ocean, which was relatively unexplored. One response to this need was conceived and intially developed in the early 1960s for a program to drill deep (5 to 10 km) beneath the ocean floor to the Mohorovicic discontinuity, or "Moho", a layer of important change of properties of the constituents of the upper mantle. Scientists hoped to be able to reach to the Moho by drilling under the ocean because the discontinuity lies much closer to the surface of the earth there than under the continents.

The early engineering trials were successful, showing that it was indeed possible to position and hold a drilling ship to the required accuracy to accomplish drilling in the deep sea. To complete such a deep hole, however, proved too expensive, and the project was cancelled. At the same time, many marine geologists felt that a higher priority project would be to make a worldwide reconnaisance of the sediments of the world's ocean basins. The new technology, developed for the Mohole, would allow scientists for the first time to collect long cores (up to 1 to 2 km) of sediment and basement rock beneath the ocean.

In order to pursue this objective, Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) was formed in 1964. The founding bodies were the Lamont-Doherty Geological Observatory of Columbia University, the Rosenstiel School of Marine and Atmospheric Science of the University of Miami, the Woods Hole Oceanographic Institution, and the Scripps Institution of Oceanography of the University of California. With Miami as the grantee of the National Science Foundation, and Lamont-Doherty as the operating institution, a drilling program was successfully completed off the Blake plateau in depths up to 1,000 meters.

Pleased with this success, the group went forward with plans to build a vessel and to nominate Scripps Institution of Oceanography as the science operator for the new program, to be called the Deep-Sea Drilling Project (DSDP). In late 1967, a subcontract was let to the Global Marine Corporation to build and opoerate a drilling research vessel. The final trials of the new vessell, named Glomar Challenger after the original H.M.S. Challenger, took place in mid-1968. The success of DSDP drew other institutions to JOIDES: the oceanographic institutions of the University of Washington, University of Hawaii, University of Rhode Island, Oregon State University, Texas A&M University, and the University of Texas at Austin all joined the consortium.

There was also strong interest from nations outside the U.S. From 1974 to 1976 five governments formally joined with the U.S. to begin the International Phase of Ocean Drilling (IPOD). The oceanographic institutions of the Federal Republic of Germany, Bundesanstalt fur Geowissenschaften and Rohstoffe; France, Centre National pour L'Exploitation des Oceans; Japan, University of Tokyo Ocean Research Institute; the United Kingdom, Natural Environment Research Council; and the USSR, Academy of Sciences, became members of JOIDES and participated as full scientific and financial partners in the Deep-Sea Drilling Project.

From 1968 until 1983, the Glomar Challenger, as the principal facility for ocean drilling, logged more than 375,000 miles on 96 voyages across every ocean. Drilling results from 1092 holes at 624 sites yielded more than 60 miles of core. The scientific results have been spectacular and unmatched in the history of geosciences.

In the late 1970s it was recognized that the Glomar Challenger was reaching the end of her useful lifetime, and that a ship with greater capabilities was needed to carry out the long-term scientific objectives of the community. The feasibility of converting the Explorer, a government-owned ship with heavy-lift capabilities, was explored, but conversion costs appeared to be too great. At the same time, a number of relatively new advanced ocean drilling vessels became potentially available with the world-wide drop in oil prices.

After reviewing the entire situation, the National Science Foundation agreed to provide the major share of funding for an international 10 year program of ocean drilling aboard a new vessel with enhanced capabilities, and Texas A&M University was selected as the new science operator. Texas A&M then selected the advanced drillship SEDCO/BP 471 for the program, and arranged for the construction of new laboratories and other structures necessary for scientific ocean drilling. Lamont-Doherty was selected to carry out the logging program, and in turn selected Schlumberger, an industry leader, for development of a logging program with the latest technology.

The conversion was completed on schedule and the new ship sailed on her maiden voyage in January 1985 with a full complement of scientists, technicians, engineers, and crew. At the present time, the full international partners in the program are the institutions as noted above from the U.S., Federal Republic of Germany, France, Japan, and the United Kingdom, and the Department of Energy, Mines, and Resources of Canada.

Biography -- Dr. D. James Baker

Dr. D. James Baker is President of Joint Oceanographic Institutions Incorporated, a non-profit research management corporation that acts as a coordinating body and systems manager for the ten largest U.S. academic oceanographic institutions. The corporation is the prime contractor for the Ocean Drilling Program and is also involved in sponsoring planning for other large multi-insitutional programs.

Dr. Baker was elected President of the Corporation in 1983, after having served as a member of the Board of Governors since 1979, and as Chairman of the Board from 1980 to 1982. Before joining JOI, he served at the University of Washington from 1973 to 1983 as Professor of Oceanography, Chairman of the Department of Oceanography, and Dean of the College of Ocean and Fishery Sciences. He has also held positions at the Pacific Marine Envirnomental Laboratory of NOAA, as a faculty member in the Division of Engineering and Applied Physics at Harvard University, at the Woods Hole Oceanographic Institution, and at the Narragansett Marine Laboratory of the Univeristy of Rhode Island.

Dr. Baker is a member of the National Academy of Sciences/National Research Council's Space Science Board and Ocean Studies Board, and he is chairman of the Committee on Earth Sciences of the Space Science Board. He is an elected member of the Council of the American Meteorological Society, and a member of the NASA Space and Earth Sciences Advisory Committee and the Earth Systems Sciences Committee.

His scientific work has been in the fields of physics, oceanography, and instrumentation, and he holds a joint patent for a deep-sea pressure gauge. He has published over 50 papers on ocean circulation, climate, polar oceanography, ocean instruments, and satellites. He was born in Long Beach, California, and attended elementary through high school there. He holds a BS degree in physics from Stanford University and the PhD in physics from Cornell University. He is married to Emily Lind Baker and resides in Washington, D.C.

MEMBER INSTITUTIONS AND BOARD MEMBERS

JOINT OCEANOGRAPHIC INSTITUTIONS INCORPORATED

University of California, San Diego, Scripps Institution of Oceanography: Dr. William Nierenberg

Columbia University, Lamont-Doherty Geological Observatory; Dr. Barry Raleigh

University of Hawaii, Hawaii Institute of Geophysics; Dr. Charles Helsley

University of Miami, Rosenstiel School of Marine and Atmospheric Science: Dr. Alan Berman

Oregon State University, College of Oceanography; Dr. Douglas Caldwell

University of Rhode Island, Graduate School of Oceanography; Dr. John Knauss

Texas A&M University, Department of Oceanography; Dr. Robert Reid

University of Texas, Institute for Geophysics; Dr. Arthur Maxwell

University of Washington, College of Ocean and Fishery Sciences; Dr. Ross Heath

Woods Hole Oceanographic Institution; Dr. John Steele

ANSWERS TO QUESTIONS FOR
Presidents of University Consortia which manage NSF's large-scale facilities

prepared by

D. James Baker, President
Joint Oceanographic Institutions Incorporated

March 27, 1986

Question

1. Please provide for the record a brief summary of:

a. the percent of the consortium's total budget provided by NSF;

Answer

in 1986 - 98.6%
in 1987 - 98.4

Question

b. the portion of the consortium's management or consultant fee received from NSF, compared to funds for research, and for facility maintenance and up-grade;

Answer

For the first three years (1978-80) of Corporate operation, NSF paid a performance fee totaling $52,742. JOI has received no management fee from the NSF since then. In FY 1985, JOI received an amount of $31,849,000 from the NSF for operation of the Ocean Drilling Program and related activities. These funds include facility maintenance and up-grade of the drillship facility.

Question

c. the portion of the consortium's funds allocated for overhead and what that overhead includes;

Answer

Of the total funds received by JOI under NSF contracts and grants, overhead accounted for 1.4% in 1985. The major items included in overhead are office expenses and rent, communications, equipment service, legal and accounting fees, salaries that cannot be readily associated with a particular contract, and depreciation of fixed assets.

Question

d. the membership fee the consortium charges to participating universities and how the fee is utilized by the consortium;

Answer

The ten academic institutions that hold membership in JOI have each contributed $12,500, all of which was paid between 1976 and 1982. No additional funds have been provided by the members since 1982. Membership fees are added to management fees to form the Corporate Fund Balance. The Fund Balance has been used to equip the staff offices and for other Corporate needs as appropriate. Examples include financing of accounts receivable; to meet short-term financial commitments; to stabilize operations in case of income fluctuations; and to fund disallowances under Federal Procurement Regulations.

Question

e. how are the consortium facilities managed to assure the equipment, instrumentation and bricks and mortar are maintained and properly renovated? Do the centers include a separate line item for this end of operations?

Answer

JOI's facilities consist of rented office space in Washington, D.C. and leased or company-owned furniture and office equipment. JOI does not maintain a national research center. Facilities for the conduct of research are provided by sub-contractor organizations either academic or industrial. Maintenance of facilities, equipment, and instrumentation is included in the program funding to these organizations.

Question

f. functions or characteristics of the consortium which are uniquely different from the other NSF large-scale facility management consortia.

Answer

The primary responsibility of JOI under an NSF contract is the management of the international program of scientific ocean drilling. The major sub-tasks are provision of scientific direction to the program through an international body of scientists, organized in a hierarchical structure and numbering approximately 200; the operation of a leased commercial ocean drilling ship especially modified for scientific drilling including archiving of deep sea cores, data processing, analysis and publication; and the provision of downhole measurements and routine logging services.

JOI operations are uniquely different from other large-scale facility management consortia in that the principal facility is a leased, commercially-owned and operated ship; scientific operations are carried out by academic institutions under sub-contract to JOI; the program receives its scientific direction from the international marine geological and geophysical community; and funding comes from six non-U.S. partner countries in addition to the U.S.

Question

2. How much overlap is there among the university members of the various consortia? Is a separate consortium required for each discipline, and why? Could management economies be realized using one university consortium as the management organization for all NSF large-scale facilities?

Answer

A given university may belong to more than one consortium if the university has more than one academic department or disciplinary interest involved in large programs or use of large facilities. Different scientific interests will be involved with each of the programs or facilities; in each case, it is the specific research interests in the university that contribute to the scientific direction of the program or facility, and hence the consortium. For example, the academic oceanographic institutions provide scientific direction for JOI and the Ocean Drilling Program; atmospheric science departments provide guidance for the University Corporation for Atmospheric Research, and so on.

In terms of whether a separate consortium is required for each discipline, one needs to separate disciplines for programs and facilities. Disciplines are supported by a variety of organizational groups ranging from small university departments to university consortia, and research funding ranging from individual grants to large national facilities and programs. The consortia serve a specific purpose at the large facility end of the spectrum. If the question refers to the need for consortia to support large facilities and programs, then I would argue that the best management requires a focus of like-minded individuals with a keen interest and expertise in a particular subject. JOI's focus on ocean drilling has led to an efficient management scheme. The specific focus would be lost if one management group tried to take on all large programs. Just as in industry, diversity and competition lead to strength and cost effectiveness.

Question

3. Do you foresee growth in the national research centers in order to provide greater access and improved capabilities?

Answer

If the nation is to stay at the forefront of research and the cutting edge of science and technology, then it has to be prepared to continue its investment in the facilties and programs that are needed to explore the fundamental nature of the world around us. Since the national centers and large facilities provide a focus for community long-term planning, their growth is inevitable both to provide the necessary improved capabilities and greater access for a broader community of scientists. The Ocean Drilling Program is a good example - the new program allows us to do much more in exploring the earth, and at the same time permits a broader access because the facilities are larger. The increase in cost is partially met by increased contribution from non-U.S. countries, so the overall program is extremely cost-effective. Programs such as ODP do not diminish the role of individual scientists performing project research. Rather they enhance the ability of individual scientists to pursue specific lines of research by providing major, common, facilities at a level of capability that no individual project can hope to achieve alone.

Question

4. What is the role of the consortium, versus the director of the national facility managed by the consortium, in setting research priorities, budget levels, personnel ceilings and salaries for the national facility?

Answer

In the Ocean Drilling Program, we have evolved over the past 17 years a scheme of setting priorities and managing the program which has proved very effective: Overall scientific priorities and long-range goals are set by the community in a periodic meeting involving a wide spectrum of participants and descriptions. The first such conference meeting, the Conference on Scientific Ocean Drilling (COSOD), was held in the U.S. in 1981 and set the stage for the current program. The second such conference is planned to be held in Europe in 1987.

Specific scientific priorities and detailed planning for each cruise leg are set by a group of working scientists called the Planning Committee (PCOM). Each paying participant in the program has a representative on PCOM. The PCOM has a series of panels drawing from the world-wide community of scientists that evaluate proposals in specific areas; the panels then recommend specific measurement programs to PCOM. PCOM recommendations are approved by an Executive Committee made up of administrative heads of the participating institutions, thus providing a check and balance to the system.

The budget level for the overall program is set by the National Science Foundation. Budget levels for the sub-elements are set by JOI in consultation with the subcontractors. The subcontractors themselves are responsible for determining the necessary personnel, salaries, and the actual operation of the program. To ensure that the subcontractors are operating in a cost-effective way, JOI continually monitors all budgets and activities. In addition, we review the entire program every two years with a Performance Evaluation Committee (PEC). The PEC recommendations are evaluated by JOI and the subcontractors and the report and JOI's recommendations for implementation are made available to the advisory committees and the NSF.

Question

5. As international participation in your research activities increases, are new problems created, (for example: obtaining permission to conduct research in the "exclusive economic zone;" political issues which could destabilize the support of the program; and intellectual partnership and scientific exchange)? How do you prepare for sustained international program support, and what is the consortium's role versus NSF's role in this regard? How do you plan to involve additional nations in the cost-sharing of your international science programs?

Answer

International participation is key to the success of the Ocean Drilling Program. Five non-U.S. countries (FRG, France, Canada, UK and Japan) soon to be joined by a 6th - the European Science Foundation - contribute directly about 1/3 of the total cost of this program that was $32.5 million in 86 and is expected to be $36 million in 87. Indirectly, they help through support in kind, by providing materials, scientists and research support to their own research institutions. Financial participation, intellectual partnership, and scientific exchange all are strong positive reasons for international participation.

As the program extends its measurement and sampling program to new regions of the global ocean, we look to research in the exclusive economic zone of countries, for example in the Indian Ocean and in the Western Pacific, that have not yet been involved in ocean drilling. We are working with our scientists to develop sufficiently broad joint activities with the scientists in these countries so that when we look for permission to drill in specific waters, we will have activities of interest being carried out on the ship with the involvement of local scientists.

In terms of financial destabilization , since the program depends on support from several countries, any drop in support level from any one of them is always a matter of concern. The reduction in available funds could cause the program to be less effective in developing new understanding of the earth, but would not lead to destabilizing the support because we could increase the contributions of the other members or we could reduce the scope of the program.

The budget level for the program is predicated on 6 foreign partners at $2.5 million each and $21 million from the U.S. (FY 1987 figures). Each country that signs on agrees in principle to supporting the program for its full 10-year period. Thus we are fully prepared for sustained international program support except as noted above. The NSF takes the lead role in developing, maintaining, and formally arranging for MOU's and transfer of funds. JOI assists NSF as required.

In our view, the advantage of additional nations in supporting the program outweigh the disadvantage of sheer numbers of participants, although at some point we would have to draw the line because of limited space for scientists on board the ship. Thus, NSF encourages countries with an interest in the program to attend meetings of the Executive Committee (EXCOM) as observers and JOI arranges for exchange visits for discussing potential participation. Examples of future potential participants that have shown interest but have not been involved before include Australia, Brazil and the People's Republic of China. A former member, the USSR, is currently evaluating their interest in rejoining the program.

Question

6. Does your organization purchase insurance for reimbursement of loss, damage, or penalty (indemnification)? What is the cost of this insurance and what level of protection is provided by insurance you purchase? Who would pay damages not covered by the insurance or if insurance protection levels are exceeded? Do you have recommendations on how indemnification should be addressed by the government?

Answer

For the Ocean Drilling Program, JOI Inc. is presently named as a co-insured on several policies covering loss of life and property, property damage (including damage to the environment) and third party liability. These policies have been placed by our lower-tier subcontractors - most notably Texas A&M Research Foundation - and have had their premium costs reimbursed through JOI Inc. with Foundation monies.

The premium amounts and thresholds of coverage are attached as Exhibit A. Brief descriptions of the types of coverage are also provided. Each policy requires individual approval by JOI Inc. and the National Science Foundation.

Should compensatory or punitive damages be assessed against JOI, its subcontractor, Texas A&M or their lower-tier subcontractor, UDI, which operates the ODP drillship, in amounts which exceed the coverages listed in Exhibit A, the National Science Foundation has agreed to consider indemnification of each to the extent that they are not covered by insurance. Any resulting indemnification would require approval of the Foundation's director, a determination of allocability and reasonableness of the claim(s), and be subject to the Congress providing adequate funds.

Given the specialized nature of ODP drilling operations and in particular the expressed policy of avoiding chance involvement with underground formations containing hydrocarbons, it is a very remote possibility that the program might incur any catastrophic loss or damage of the type feasible with offshore platforms/vessels engaged in drilling for oil and gas. As a case in point, the predecessor program, the Deep Sea Drilling Project aboard Glomar Challenger experienced no such problems in 15 years of scientific ocean drilling. It is also unlikely that any damages involved in a catastrophic occurence would exceed the $200 million insurance "umbrella" coverage being provided by Lloyd's of London (this being a coverage requisite for the Government to consider indemnification).

Drillship operators are usually dependent upon the indemnification protection provided to them by the large oil companies. Although the risk inherent to the Ocean Drilling Program is small in comparison to oil exploration, the drillship subcontractor requested that Texas A&M use its "best efforts" in obtaining indemnification as a normal course of doing business. The National Science Foundation was authorized to provide this indemnification and so reassure all parties involved of the Government's commitment to fully support the drilling effort. Because indemnification authorization costs the Government nothing unless a catastrophe occurs - in which case the Government would most likely be named as a party to any resulting suit anyway - and since the chance of such indemnification being invoked is so very small, we concur with the Foundation's current indemnity commitment.

Question

7. What effort do you make to increase the number of universities which are members of your consortium? What is being done to assure that talent in non-member universities is involved in the consortium research planning and priorities?

Answer

Membership in the Corporation is open to all institutions with the qualifications and interest in participating fully in the Ocean Drilling Program. Such qualifications include a certain size and level of activity, and a willingness to host the planning office for ODP as it rotates among the institutions. The latest new member of the Corporation is the University of Texas at Austin, which joined in 1980. The Corporation periodically reviews the qualifications to ensure that they are sufficiently broad to include the major U.S. institutions interested in ocean drilling.

We make a broad and concerted effort to involve the best talent in the country whether from member or non-member institutions and from industry and government as well as academia, in the scientific planning and setting of priorities for ocean drilling. The COSOD's typically involve one-hundred-fifty participants, only one-third of whom are from JOI institutions. The panels of the PCOM, our chief scientific committee over the years have involved more than four hundred scientists from a total of fifty institutions. We have found that this broad scientific involvement is key to the intellectual viability of the program.

Question

8. Is your contract with the National Science Foundation clear as to what the consortium manages, how and what the lab or project director manages, and what the responsibilities are of the NSF and National Science Board? Please describe policies and criteria which clarify these responsibilities.

Answer

The contract between the National Science Foundation (NSF) and Joint Oceanographic Institutions Incorporated (JOI) is clear as to JOI's management of the ODP. A portion of the introduction to Prime Contract OCE 83-17349 is quoted:

> "The ODP will be a long-term program of fundamental research on the earth's crust beneath the ocean. The scope is global, extending eventually into every ocean on a carefully-scheduled program of research. The research agenda addresses some of the most important problems in the earth sciences that are concerned with the structure, processes and evolution of the crust of the earth.
>
> "Scientific planning for the ODP will be provided primarily by the international scientific committee structure of JOIDES--the Joint Oceanographic Institutions for Deep Earth Sampling. It is the intent of the Foundation to have the scientific planning to be in agreement with the Memoranda of Understanding between the Foundation and the international partners. If the Contractor perceives a conflict between any Memorandum of Understanding and the contract, he shall notify the Contracting Officer immediately in writing requesting a decision as to how to proceed in performance of this contract.
>
> "The Ocean Drilling Program will constitute a unique mix of national and international scientific institutions and facilities. This contract provides for the management structure necessary to the successful execution of the program.

"Joint Oceanographic Institutions Incorporated (hereinafter referred to as the Contractor) a consortium that represents major oceanographic institutions in the United States will manage the program under the terms and conditions of this contract and an annual program plan. This program plan will be developed by the Contractor in consultation with the Program Officer, and approved in writing by the NSF Contracting Officer."

The following description clarifies the responsibilities of the overall program management:

The Ocean Drilling Program is managed by Joint Oceanographic Institutions Incorporated (JOI Inc.) as the prime contractor to NSF. JOI is a non-profit consortium of ten major U.S. oceanographic institutions which provides management support to large U.S. and multi-national scientific research programs. The overall objectives of ODP are established by JOIDES, the international body of scientists drawn from U.S. institutions and non-U.S. partner nations. JOIDES provides overall science planning and program advice with regard to the scientific goals and objectives, facilities, scientific personnel, and operating procedures.

Science operations are carried out by Texas A&M University (TAMU), under contract to JOI, which manages the operation of the drillship, plans and implements the scientific cruises. TAMU has facilities that serve as a repository for ODP cores and recently collected cores from the predecessor scientific ocean drilling program. As science operator, TAMU is further responsible for implementing science planning and operations; engineering development and improvement of drilling technology; selecting scientists for the shipboard scientific party; designing, furnishing, and maintaining shipboard and shorebase laboratories; curating and distributing all core samples and data; publishing scientific results; and providing public information about ODP.

The Lamont-Doherty Geological Observatory (L-DGO), under contract to JOI, manages the wireline logging operations for obtaining electronic measurements in the drill holes.

The JOIDES Office, under contract to JOI, provides support for the JOIDES Executive and Planning Committees and for the science advisory structure in general.

International participation in ODP is established by a Memorandum of Understanding between the National Science Foundation and the responsible funding agency in the non-U.S. partner nation. The articles from the Memorandum of Understanding for regular membership in the Ocean Drilling Program outline the relationship between NSF and the non-U.S. partner agency.

The Ocean Drilling Program office in NSF is responsible for oversight of the program and for administering comingled funds from the NSF and the non-U.S. partner nations. The NSF convenes an annual meeting of the International ODP Council and acts as permanent chairman of this consultative body. The Council itself provides a means of communications between NSF and other international funding agencies.

EXHIBIT A

SUMMARY OF ODP INSURANCES

Type of Insurance	Policy Number	Carrier	Limit	Deductible	Policy Dates	Premium
Employer's Liability & Maritime Employer's Liability	50 AET 34213	Aetna Insurance Co.	$ 1,000,000	None	8/24/85 - 12/1/86	$161,000*
Comprehensive General & Automobile Liability	45 AET 34212	Aetna Insurance Co.	$ 1,000,000	None	8/24/85 - 12/1/86	$ 55,200*
Umbrella			$200,000,000	None		
1st Layer	22675	Americas Insurance Company	$10,000,000		12/1/85 - 12/1/86	$ 50,000
2nd Layer	36391	Lloyd's of London thru Southern Marine & Aviation Underwriters, Inc.	$65,000,000		12/1/85 - 12/1/86	$ 70,000
3rd Layer	36392	"	$75,000,000		12/1/85 - 12/1/86	$ 80,000
4th Layer	85-1080	Mutual Marine Office All American Marine Slip New York Marine Mgrs. Texas Marine Managers J.H. Blades & Co., Inc.	$50,000,000		12/1/85 - 12/1/86	$ 50,000
Seepage & Pollution Liability	ON85-1086	Lloyd's of London thru SHIS, Inc.	$ 1,000,000	$ 10,000	1/6/86- 11/30/86	$ 22,534
Control of Well	36402	Lloyd's of London thru Southern Marine Aviation Underwriters Inc.	$10,000,000	$ 25,000	1/10/86 - 12/1/86	$ 30,000*

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Type of Insurance	Policy Number	Carrier	Limit	Deductible	Policy Dates	Premiums
Third Party Property Floater	22684	American Insurance Co.	$ 5,000,000	$ 10,000	1/30/86 - 12/1/86	$ 5,200*
Cargo	22621	American Insurance Co.	$ 1,000,000	$ 2,500	6/3/85 - 6/3/86	$ 5,000
Non-Owned Aircraft	360AC-118355	USAIG	$ 5,000,000	None	10/7/85- 10/7/86 .	$ 2,500
Hull & Machinery All Risks Removal of Wreck	CHIC 151	Various thru Cumberland Hill Insurance Co., Ltd.	$ 55,000,000 $ 25,000,000	 $250,000 $250,000	5/1/85 - 10/1/86 "	(Annual) $231,555

* Deposit premiums - Adjustable subject to audit (at policy year end)

February 11, 1986

236

Answers to Specific Questions for Joint Oceanographic Institutions Incorporated

Question

1. What role does the Joint Oceanographic Institutions Inc. (JOI) play, or plan to play, in the development of an international strategy for global geoscience research? Was JOI involved in the development of the NSF Global Geoscience Program? What is your view of the scope and support given to the NSF Global Geoscience Program in the FY 1987 budget? Does the NSF program adequately incorporate the international focus on the International Geosphere-Biosphere Program?

Answer

As I indicated in my testimony, the U.S. and the international science community is rapidly coming to agreement that the global view of geosciences is key to understanding the earth and that such a global view is now possible. JOI plays a role in the development of international strategy for global geoscience research by providing administrative support for the planning and implementation necessary to establish new large global programs in oceanography and could play a role by providing management support for the operation of large facilities for global ocean research should the ocean community and the National Science Foundation deem such a role to be appropriate.

To date, JOI, with funding from NSF, has given administrative support to planning committees for the World Ocean Circulation Experiment and the Global Ocean Flux Study. Each of these is a key element in the global geoscience program as defined by NSF. It is my personal view that the scope and support given to the NSF global geoscience program in the FY 1987 budget is entirely consistent with the urgent need for such research and with our ability as a scientific community to use such new resources in an efficient and effective way. I also believe that the NSF program, by supporting a number of activities such as the Tropical Ocean Global Atmosphere program, WOCE, and GOFS which are inherently international, is in fact doing an excellent job of incorporating the international focus on these programs which are fundamental to the development of a successful International Geosphere-Biosphere Program.

Question

2. On the last page of your testimony, you note that JOI plays a key role in developing a consensus in ocean sciences through bringing together groups of scientists and engineers in working groups.

Is this activity a part of JOI's NSF contract?

Consensus building in many other sciences is done through National Academy of Sciences (NAS) Committees. Are JOI and NAS both developing consensus statements, plans, and publications in the ocean sciences?

Answer

As mentioned above, JOI has been provided with funding from NSF for administrative support of planning committees in the WOCE and GOFS programs. In addition, JOI has provided administrative support with funding from NASA for planning committees on oceanography from space and on the earth's magnetic field. Provision of such support is a part of JOI's charter, as a corporation, and in each case is supported through a grant or contract for that specific purpose. The contract for the ocean drilling program is a separate management activity, and includes support for planning and implementation of scientific ocean drilling.

We view consensus building as a pluralistic activity. The NAS studies are aimed at defining the long-range plans and broad structural definitions for programs; such studies play a key role in building consensus in many key areas of science, including oceanography. JOI planning aims at the short range, looking to operational and implementation plans, only be drawn on if the specific community desires a JOI activity in preference to other administrative support. In no case would we or do we carry on simultaneous or duplicative activities.

Question

3. Access to much of the ocean is controlled by underdeveloped countries which have neither the financial nor scientific resources to participate in the international ocean drilling program.

What plans do you have for involving these countries so they can participate in the program and benefit from drilling in the ocean zones which they control?

Answer

Access to waters controlled by underdeveloped countries and involvement of these countries in the science and operations of ocean drilling has been a topic of keen discussion since the establishment of the program. We are currently pursuing these directions to address the issue:

(1) Our Executive Committee for Ocean Drilling has agreed that each partner will identify and fund the participation of underdeveloped countries directly as a bilateral activity. In this way, the scientist from the smaller country can not only go aboard the drillship, but can also spend time in a laboratory in

the host country coming "up to speed" in terms of science, so that the experience is fully utilized.

(2) Whenever clearance is obtained for scientific drilling within waters controlled by any country, that country's scientists are invited to participate aboard ship, and the scientific results of the cruise are freely given to that country.

(3) We are developing a proposal to an international foundation specifically for the support of scientists from underdeveloped countries to spend time in a host laboratory and to go aboard the drillship. We are optimistic that such a proposal will be funded in the next few months.

We feel that by involving the scientists directly in the program, we can generate a joint interest in ocean drilling in general and in the local area specifically so that the program as a whole and the local country both benefit from the new knowledge.

Mr. **Walgren**. Thank you, Dr. Baker.

Next, is Dr. Hughes.

Dr. **Hughes**. Thank you, Mr. Chairman.

I am pleased to be able to join this discussion of the national centers that are supported by the National Science Foundation.

In addition to my prepared testimony, I have also submitted a brief profile of the National Radio Astronomy Observatory, and I hope that it will be included in the record.

In thinking over the subject matter of this hearing, I chose to focus upon three major questions that describe the essential interactions between the National Science Foundation and all of the centers, including NRAO.

The first is: How well does the National Science Foundation divisional structure deal with its oversight responsibilities for the operation of its national centers?

Second, how well does the NSF divisional structure deal with the detailed distribution of funding within a given discipline once the total allocation to that division has been determined?

And, third, how well does the national system function in determining the optimum allocation of available funding to the diverse fields of science that it supports?

While the NSF is enjoined from operating its own research institutions, it does have a clear oversight responsibility to ensure the proper and effective use of its awards. And from my own personal experience, first, as a long-time professor at Cornell University and director of the Materials Science Center, which was one of the largest materials research laboratories supported by the NSF, later as the assistant director of the National Science Foundation for AAEO, and now as president of AUI, the organization that runs the National Radio Astronomy Observatory, it is my judgment that in dealing with its national centers, NSF has done an outstanding job in meeting these oversight responsibilities.

Appropriate review and audit mechanisms are in place, and the staff maintains close liaison with the operations and planning functions of the centers.

This is not to say that issues and debates do not arise from time to time. No institutional arrangement is perfect. But concerns of overzealousness or management intrusions that occasionally arise from both sides are resolved in the strong mutual sense of purpose shared by the centers and the Foundation staff.

Overall, the record that has been established at the centers in bringing major new projects and facilities to successful fruition is one in which all concerned can take pride.

In response to the second question, I would also give the Foundation very high marks for its role in the equitable distribution of the funding that each year is finally allocated to specific disciplinary areas. It must be recognized that this is an extremely difficult business.

There is no uniquely correct solution in any field of science. Rather, a rough but thoughtful consensus must be extracted from many strong and often divergent inputs. To mention just a few that the people at the Foundation have to deal with in trying to make decisions as to how to allocate funds within a given discipline, you have major national studies.

In astronomy, you have the Whitford Report in 1964; you have the Greenstein Report in 1972; you have the Field Report a couple of years ago; and in between, the Dicke Report, and others as well; committee reports, the advisory committees to NSF; advisory panels; merit reviews; new initiative proposals; technological and instrumental advance that change the prospects for the future, have to be considered; the renaissance of mature areas within the science—a sudden discovery and you can shift the bias and structure of the internal funding very sharply—the historic alignment of subdisciplines, the sociology of science is such that these exist and they are often slow to change; the impact of strong personalities exist in science as elsewhere—and the recognition of new responsibilities in areas such as equal opportunity, education, computing, and national economic programs.

Working within such constraints, the NSF divisional staffs must develop annual and long-range programs that protect the basic backbone of the sciences they serve and, at the same time, stimulate new exciting progress. And all of this must be done in areas of intellectual activity where truly significant advances are measured in units of 5 or 10 years at best. That is not an easy task.

Given the absolutely critical role NSF funding serves in many of the sciences it supports, it is remarkable that the system works as well as it does.

Mr. Chairman, in your letter of invitation to this hearing, you indicated that you would be interested in observations on the adequacy of resources that are being made available to support maximum utilization and future improvements of facilities at the national centers.

I would respond by saying that, by definition, every well-managed, dynamic research organization has, at ready, important new projects and programs that simply cannot fit within their current budget structures.

By definition, priority listings of future activities are continuously reviewed in a first-class organization in a churning climate of new ideas and new developments.

In the field of ground-based astronomy, which is principally supported by the NSF, such opportunities do exist at the centers. But other priorities must also be met.

Over the past 15 years, the operations and research budgets available to all of the national centers in astronomy have been essentially constant—15 years in constant dollars. The budgets to support the university-based programs have increased only slightly over that period.

Now, throughout the entire community there is a shared understanding that university-based research is absolutely critical to the intellectual development of science, and that university students are the lifeblood of the future of the field.

In view of this, I see no rational basis for significant departures from the overall distribution of the available funding that has been developed within the astronomy division at the NSF.

Now, the third question I raise is a vexing one. How are national priorities to be set amongst the complex of disciplines and major new programs that clamor for attention and support? This was the question that you raised earlier this morning with respect to the other panel.

You will not be surprised if I offer no new panaceas. Your own committee is now engaged in a comprehensive study of the many issues that underlie this question.

Perhaps the most characteristic and dominating aspect of the process is the annual budget cycle that seemingly, without beginning or end—and I am sure it must seem that way to you—continuously occupies the attention and the energies of the leadership in the scientific communities, in the Federal agencies, and in the Congress.

While this assures a certain level of review and perhaps encourages the introduction of newly packaged initiatives, the ever-present uncertainties in the outcomes make long-range planning difficult in many fields.

The impact of such uncertainties is particularly damaging in fields of science where future progress is heavily dependent upon the design, the development, the construction, and the operation of large facilities. Such facilities require years of planning and cooperative effort throughout the community, first to establish the scientific need and then to develop the design parameters.

The VLA, the very large array, in Socorro, NM, was conceived in the early sixties; work began on it in 1964; it was completed in 1980. So, there is a period of 16 to 18 years.

This must be followed by research and development to validate the final systems design. Whole segments of the community, and that includes the university community as well as the observatory community, must commit and in some sense gamble significant factions of their careers in such enterprises.

Willingness to undertake such gambles fades in long periods of uncertainties, and the future vitality of the science can be affected.

Major facilities typically remain productive for as much as a quarter of a century, or more. Construction and future operating costs can and should, in some sense, be amortized over appropriate periods and recognized as a necessary element in the overall budget structure of a given science. This can best be done through long-range planning that provides a measure of stability, promotes optimum efficiency in the use of Federal funding, and recognizes the necessity for short-term fluctuations in the budgets during periods of construction.

This is not a problem that is unique to astronomy, where long-range planning within the community has been vigorously practiced for more than two decades. Many fields that have traditionally relied upon small individual grants are now discovering that modern technology can open new vistas through large centralized shared facilities or through major national or international programs of the type we just heard about.

Thus, for example, materials scientists, chemists, and solid state physicists are now contemplating the need for a new powerful synchrotron light source that will have a price tag in the order of magnitude of $250 million. Now, in such communities former distinctions that were characterized with big science and small science labels are disappearing, and it is critically important that these changes be widely be recognized and understood.

Mr. Chairman, you addressed this question to the earlier panel. I would simply add a comment that there is some danger in trying to develop a simplified overview of this problem, because it varies so much from field to field. In astronomy, astronomers are totally dependent upon the availability of central major facilities. You cannot put major telescopes at every institution.

And so the development of centers in such a field occurs with the continuous input of all the scientific community. It is a shared experience, and the NSF staff shares that experience as well.

Thank you.

[The prepared statement of Dr. Hughes, a profile of Associated Universities, Inc. and of the National Radio Astronomy Observatory, and answers supplied to questions for the record follow:]

Statement of Dr. Robert E. Hughes
President of Associated Universities, Inc.
To The Subcommittee on Science, Research and Technology
Of The Committee on Science and Technology
Washington, D.C. February 25, 1986

Mr. Chairman, I thank you for the opportunity to participate in this discussion of the roles and status of the National Centers that are funded by the National Science Foundation. As you know, I am president of Associated Universities, Inc. (AUI), an independent, non-profit research management institution. AUI was chartered some forty years ago primarily for the purpose of founding Brookhaven National Laboratory which it has operated ever since, first for the AEC, later for ERDA and now for the Department of Energy. About thirty years ago, AUI participated with the National Science Foundation in the establishment of the National Radio Astronomy Observatory (NRAO), the first National Center in astronomy. AUI has operated NRAO ever since, under a contract with the NSF.

We have prepared some supplementary material that provides a brief profile of NRAO. With your permission, I would like to submit it for the record.

I will be brief and limit my discussion to three basic questions:

(i) How well does the NSF divisional structure deal with its oversight responsibilities for the operation of its National Centers?

(ii) How well does the NSF divisional structure deal with the detailed distribution of funding within a given discipline once the total allocation to that division has been determined?

(iii) How well does the national system function in determining the optimum allocation of available funding to the diverse fields of science it supports?

While the NSF is enjoined from operating its own research institutions, it does have a clear oversight responsibility to ensure the proper and effective use of its awards. In dealing with its National Centers, the NSF has done an outstanding job in this regard. Appropriate review and audit mechanisms are in place and the staff maintains close liaison with the operations and planning functions of the Centers. This is not to say that issues and debates do not arise from time to time. No institutional arrangement is perfect. But concerns of overzealousness or management intrusions that occasionally arise from both sides are resolved in the strong mutual sense of purpose shared by the Centers and the Foundation staff. Overall, the record that has been established at the Centers in bringing major new projects and facilities to successful fruition is one in which all concerned can take pride.

I would also give the Foundation very high marks for its role in the equitable distribution of the funding that, each year, is finally allocated to specific disciplinary areas. It must be recognized that this is an extremely difficult business. There is no uniquely correct solution in any field at any given time. Rather, a rough but thoughtful consensus must be extracted from many strong and often divergent inputs. To mention just a few, there are major national studies, committee reports, advisory panels, merit reviews, new initiative proposals, technological and instrumental advances, the renaissance of mature areas, the historic alignments of important sub-disciplines, the impact of strong personalities and the recognition of new responsibilities in areas such as equal opportunity, education, computing and national economic progress.

Working within such constraints, the NSF divisional staffs must develop annual and long-range programs that protect the basic backbone of the sciences they serve and stimulate new exciting progress. All of this in areas of intellectual activity where truly significant advances are measured in units of five or ten years at best. Given the absolutely critical role NSF funding serves in many of the sciences it supports, it is remarkable that the system works as well as it does.

Mr. Chairman, in your letter of invitation to this hearing you indicated that you would be interested in observations on the adequacy of resources that are being made available to support maximum utilization and future improvements of the facilities at the National Centers. I would respond by saying that, by definition, every well managed, dynamic research organization has, at ready, important new projects and programs that simply cannot fit within its current budget structure. By definition, priority listings of future activities are continuously reviewed in a churning climate of new ideas and new developments. In the field of ground based astronomy, supported by the NSF, such opportunities do exist but other priorities must also be met. Over the past fifteen years, the operations and research budgets available to all of the National Centers in astronomy have been essentially constant in constant dollars. The budgets to support the university based programs have increased only slightly in this period. Throughout the entire community there is a shared understanding that university based research is absolutely critical to the intellectual development of the science, and that university students are the lifeblood of the future of the field. In view of this, I see no rational basis for significant departures from the overall distribution of the available funding that has been developed within the Astronomy Division at the NSF.

The third question is a vexing one. How are national priorities to be set amongst the complex of disciplines and major new programs that clamor for attention and support? You will not be surprised that I offer no new panacea. Your own Committee is now engaged in a comprehensive study of the many issues that underlie this question. Perhaps the most characteristic and dominating aspect of the process is the annual budgeting cycle that, seemingly without beginning or end, continuously occupies the attention and energies of the leadership in the scientific communities, in the federal agencies and in the Congress. While this assures a certain level of review and perhaps encourages the introduction of newly packaged initiatives, the ever present uncertainties in the outcomes make long-range planning difficult in many fields.

The impact of such uncertainties is particularly damaging in fields of science where future progress is heavily dependent upon the design, development, construction and operation of large facilities. Such facilities require years of planning and cooperative effort throughout the community, first to establish the scientific need and then to develop the design parameters. This must be followed by research and development to validate a final systems design. Whole segments of the community must commit, and in some sense gamble, significant fractions of their careers in such enterprises. Willingness to undertake such gambles fades in long periods of uncertainties and the future vitality of the science can be affected.

Major facilities typically remain productive for a quarter of a century or more. Construction and future operating costs can and should, in some sense, be amortized over such a period and recognized as a necessary element in the overall budget structure of a given science. This can best be done through long-range planning that provides a measure of stability, promotes optimum efficiency in the use of federal funding and recognizes the necessity for short-term fluctuations during periods of construction.

This is not a problem unique to astronomy where long-term planning within the community has been vigorously practised for more than two decades. Many fields that have traditionally relied upon small individual grants are now discovering that modern technology can open new vistas through large centralized facilities or major national or international programs. Thus, for example, materials scientists, chemists and solid state physicists are now contemplating the need for a new powerful synchrotron light source. Big science, small science barriers are disappearing in many communities and it is critically important that these changes be widely recognized and understood.

Associated Universities, Inc.
A Brief Description of Its Role and Activities

Associated Universities, Inc. (AUI) is an independent non-profit organization incorporated on July 18, 1946, under an absolute charter granted by the Board of Regents of the University of the State of New York Education Department. The principal purposes for which the corporation was formed are:

> "To acquire, plan, construct and operate laboratories and other facilities, either under contract with the Government of the United States or its agencies or otherwise, for research, development and education in the physical and biological sciences, including all aspects of the field of nuclear energy and its engineering and other applications, and to educate and train technical, research and student personnel in said fields, and also to engage in research in the social sciences;
>
> "To constitute an agency through which universities and other research organizations will be enabled to cooperate with one another, with the Government of the United States and with other organizations toward the support and use of the laboratories and other research facilities and toward the development of scientific knowledge in the fields hereinabove set forth..."

The universities that cooperated in the establishment and sponsorship of the corporation are: Columbia University, Cornell University, Harvard University, Massachusetts Institute of Technology, Princeton University, The Johns Hopkins University, University of Pennsylvania, University of Rochester and Yale University.

The fiduciaries of AUI constitute a self-perpetuating Board of Trustees of twenty-four individuals that oversees the management of the corporation and its facilities. Thus, AUI is not a consortium or a membership organization. Historically, the majority of the Trustees has been drawn from the administrative and scientific staffs of the nine founding universities, but, over the years, some thirty-five Trustees, or exactly one-quarter, have been elected from other universities, research institutes and industrial organizations across the country. It is anticipated that this fraction will increase in the future.

Since AUI is not a membership organization individual Trustees do not represent their home institutions on the Board. This is entirely analogous to the normal role of a Trustee on the Board of a major university. The fundamental principle that guides the selection of new Trustees is the maintenance of an appropriate balance of skills and experience on the Board to deal effectively with current and projected areas of activity.

Perhaps the greatest strength of AUI as a research management institution is the fact that its Board of Trustees has always been broadly and solidly based in all major areas of science and administration. Thus, at present, individuals of distinction provide insight and experience in radio astronomy, solar physics, astrophysics, engineering, accelerator physics, nuclear physics, particle physics, atomic and solid state physics, metallurgy, electronics, computing, chemistry, biochemistry and medical science. More than two-thirds of the members have had substantial experience as senior administrators with major responsibilities. This breadth of experience and backgrounds ensures that wide ranging policy issues can be considered with an absolute minimum of partisanship and institutional rivalry. It also effectively eliminates micromanagement of the AUI institutions and thereby provides clearly focused responsibilities and authorities for the Directors of these institutions.

AUI views itself as a national institution dedicated to the development and management of large-scale research facilities that demonstrably fulfill a national need and serve a national scientific community. Such facilities, funded by appropriate agencies of the Federal Government, are generally operated as National Centers when their size and complexity make them inappropriate for operation within the framework of a single university. The AUI facilities are staffed by scientists, engineers and supporting personnel with two broad areas of responsibility: (i) to provide the scientific and technical support required to develop and maintain forefront facilities that are primarily for the use of the university research community but which are also available to industrial scientists, and (ii) to develop and maintain research programs of the highest quality that are relevant to the purposes of the institution and to the broad missions of funding agencies. All institutions managed by AUI must be centers of excellence in their own right, with staffs of the highest caliber comparable to the faculty and staff of a major research university.

AUI Visiting Committees are established to provide the Board of Trustees with independent, expert appraisals of the scientific programs at the laboratories managed by the corporation. Each Committee is expected to maintain a systematic schedule of review that encompasses all programs under its purview and to provide responsible judgments on the quality, scope and directions of these programs. The Trustees attach great importance to the appraisals and recommendations that are provided by the Committees in annual written reports and through formal and informal meetings. It is also recognized that the Committee reports are of great value to the Laboratory and Observatory Directors and to their senior management staffs and Department Chairmen.

The Committees are composed of distinguished scientists from the national and international scientific communities and are drawn from public and private institutions external to AUI's operating entities. The Committees are structured by the Board to maintain expertise that spans the scientific and technical fields of importance to the disciplines and departments under review.

The Visiting Committee for the National Radio Astronomy Observatory (NRAO) has eight members with terms of four years each. Thus, two members are replaced each year. The Committee holds a formal review meeting each year at an operating facility of the Observatory and an experienced member is designated each year to chair the Committee's operations. Two or more Trustees are appointed annually by the Chairman of the Board to participate in the meetings of the Committee.

Responsibilities of Trustees of AUI

The Trustees of AUI, as the governing body of the corporation, are responsible for its overall management and the direction of its activities. Within this broad charge, the Board in the discharge of some of its more important responsibilities:

1. Adopts By-laws;

2. Elects members of the Board as provided in the By-laws;

3. Selects the President of AUI to serve under terms and conditions mutually agreed upon between the President and the Board;

4. Establishes and appropriately reviews policies governing the development, management and operations of the corporation and of institutions for which it is responsible;

5. Appoints the Directors of the research institutions and annually reviews their performance, and at appropriate intervals, not to exceed five years, requests the President, on behalf of the Board, to conduct a more extensive formal review of each Director's performance;

6. Maintains a continuing review of corporate activities and oversight of institutional activities including: (i) scientific and professional staff appointments, the quality of research output and the fulfillment of obligations to DOE, NSF and other funding agencies, (ii) maintenance of constructive relationships with the academic community and the scientific community at large, (iii) effectiveness in collaborative and service relationships with institutions of higher education, industry and other interested organizations, and (iv) maintenance of cordial and constructive relationships with Federal agencies and with local institutions and governments impacted by the institutions' presence;

7. Approves all appointments with tenure to the scientific and professional staffs of the corporation's operating institutions; approves all appointments and all salary changes for personnel with salaries above levels to be set from time to time; and reviews appointments to key administrative positions, e.g., scientific department heads and senior management personnel;

8. Reviews all long-range planning and proposed changes in the missions of the institutions;

9. Reviews and approves the corporate budget annually;

10. Reviews budget proposals for annual or longer term funding and long-range projections prepared by the institutions for submission to funding agencies. Reviews and approves, or delegates responsibility for, all contractual relationships between AUI and other agencies or organizations from which financial support for its operation may be obtained; and

11. Assists in identifying opportunities to undertake, in the national interest, additional research and management tasks in support of appropriate research and educational activities.

Responsibilities of the President of AUI

The President is the Chief Executive Officer of AUI and is responsible to the Board. The President is elected at the annual meeting of the Board for a term of one year, but serves at the pleasure of the Board. The President is assisted in the discharge of his responsibilities by other officers of the corporation elected in accordance with the By-laws, all of whom, except the Chairman of the Board, report to the President, and by such additional staff as may be appointed from time to time with the approval of the Board. The President:

1. Is responsible for the implementation of all policies established by the Board and for keeping the members of the Board fully informed on all important matters affecting the quality and financial integrity of AUI and the institutions it manages;

2. As mandated by the Board, and with the assistance of a Special Review Committee appointed by the Chairman of the Board, will review and assess the performance of the Directors. Guidance for the conduct of these reviews will be provided by the Board;

3. Is responsible for establishing and maintaining effective relationships with the DOE, the NSF, and with such other funding agencies as may become involved in the support of operations for which AUI now has or in the future assumes developmental and/or operating responsibilities. The President may be assisted in these matters by the Trustees and the Directors and members of the staff of each of the operating institutions in such manner as may be deemed desirable. The President by virtue of overall responsibility for the corporation's relations with its funding agencies also has general responsibility for communication with those agencies. However, this latter responsibility, except for contractual relations and matters of fundamental importance to institutional operations, is ordinarily discharged by delegation to the Directors;

4. Is responsible for the maintenance of cordial and effective working relationships with the Presidents and principal officers of the institutions that are concerned with the programs and operations of AUI;

5. With the knowledge and approval of the Board, seeks opportunities for AUI to undertake in the national interest and in the interests of its sponsoring institutions and the academic community, additional developmental and management tasks in support of appropriate research and educational activities;

6. Chairs meetings of the Board and the Executive Committee in the absence of the Chairman;

7. In the event of absence or possible unavailability, may authorize any other officer of the corporation to exercise any and all of the authority of the President for such a period as the President deems appropriate; and

8. Has such other powers and duties as usually pertain to this office with such additions or limitations as may be prescribed by the Board.

Responsibilities of the Directors of BNL and NRAO

1. The Directors of BNL and NRAO serve at the pleasure of the Board and report to the President. The Directors are the chief operating officers for their respective institutions with primary responsibility for program, both content and quality, and representation of the institution to the sponsoring agency. This administration and management must be carried out within the policies and practices of AUI and within the contractual terms and guidelines of the sponsoring agency.

2. The Directors are expected not only to ensure the maintenance at their institutions of research programs of the highest quality but also to be continually alert to the possible need for changes in emphasis among particular areas of research within the programs of their institutions. The appropriateness of the current "mix" of research concentrations is reviewed periodically and discussed with the President, Vice President - Programmatic Affairs, and the Board with particular concern for the quality of the laboratory's entire program and its relevance to the objectives and purposes of AUI.

3. The Directors are responsible, personally and through the work of their associates, for recruiting staff members of the highest quality for their operations, subject to the approvals required by the Trustees.

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A BRIEF PROFILE OF THE NATIONAL RADIO ASTRONOMY OBSERVATORY

Since its funding in 1957, the National Radio Astronomy Observatory (NRAO) has been a major force in the development of radio astronomy in the United States and throughout the world. This field, pioneered in this country, has blossomed to become a central element of modern astronomy.

At the present time, the Observatory operates three major sites from its headquarters complex in Charlottesville, Virginia. The 300-foot diameter meridian transit telescope and the 140-foot diameter fully steerable telescope are both located at the original Green Bank, West Virginia site; the Very Large Array (VLA) telescope, a mobile array of twenty-seven 25-meter antennas, is located on the Plains of San Agustín near Socorro, New Mexico; and the 12-meter diameter millimeter-wave telescope located on Kitt Peak near Tucson, Arizona. Operation of the three-element interferometer, also located in Green Bank, West Virginia, was discontinued for astronomical observing in 1978 when the VLA became operational; it is now operated by the NRAO exclusively for the U.S. Naval Observatory for purposes of time-keeping. NRAO is constructing a new telescope, the Very Long Baseline Array (VLBA). The VLBA, like the VLA, is a synthesis telescope simulating an extremely large single antenna by a distribution of smaller antennas operating in concert with exquisite precision. In the case of the VLBA, the individual antennas will be spaced from Hawaii to the Virgin Islands and controlled from an operations center in Socorro, New Mexico.

The NRAO is operated by Associated Universities, Inc. (AUI), an independent not-for-profit research management corporation, under the terms of a contract between the National Science Foundation (NSF) and AUI. The following responsibilities for AUI are included in the Scope of Work of this contract:

- Staff, manage, operate, and maintain the facilities ... of [the] Observatory ...;
- Provide scientific, managerial, and logistic support in the conduct of research programs in radio astronomy and related fields. The research shall be carried out by the staff of the Observatory, and visiting scientific investigators. The scientific merit of research proposed by visiting scientific investigators and by the Observatory staff shall be given the same consideration. The major criteria for the utilization of Observatory facilities shall be the scientific merit of the proposal, the competence of the individual or individuals, and the suitability of the Observatory facilities.
- Maintain a broad base research program at the Observatory in order to promote advances in and the utilization of knowledge in astronomy.
- Provide facility and logistic support to university and NRAO research programs in radio astronomy and related fields.

- Engage in education programs in radio astronomy and related fields as may be appropriate to the operation of the Observatory and as is consistent with the Program Plan.
- Critically evaluate the scientific community's needs for specialized and costly facilities which would be appropriate for the Observatory to provide.

These contractual requirements have characterized the role of the NRAO since it was founded.

The concept of a national observatory was unique when it was proposed in 1954--NRAO was the first national astronomical observatory. There were some who doubted that an open, visitor-oriented, national facility could efficiently serve its user community and at the same time provide a research environment that would be conducive to competitive research. The fact that NRAO has established and maintained the world standard in radio instrumentation and user service, together with the remarkable flood of scientific results from its users, is ample justification for the wisdom of providing such facilities.

USERS

The principal responsibility of the Observatory is to provide the astronomy community access to forefront research capabilities through the development of major national facilities. How large is NRAO's user group? What is its composition? What institutions do they represent?

What is the participation of students? Is the Observatory primarily serving its external users or its own research staff?

Figure 1 shows the annual growth in the user group over the history of the Observatory, from the modest beginnings, before the first major telescopes were built, to over 650 long and short-term visitors today. The largest increase in the number of visitor-users occurred as the VLA entered full operation in 1981. The use by Observatory staff, both permanent scientists and postdoctorals (Research Associates) can be seen to represent about 7% of all Observatory users.

The number of institutions using NRAO telescopes has also grown dramatically over the years, with a 50% increase attributable to the VLA. Universities represent 64% of the institutions, other observatories and government laboratories 33%, and private industries the remaining 3%. The overwhelming majority of these institutions lack the resources to design, build, maintain, and operate telescopes comparable to those at NRAO. Nevertheless, many of these institutions actually participate with NRAO in the design and fabrication of sub-elements of advanced systems. This includes not only individual groups but also working teams operating out of universities and government laboratories. Maintenance of such capabilities in these institutions is an important aspect of NRAO's role as a national observatory.

It is also important to note that in keeping with a growing interdependence of all areas of astronomy, the NRAO user community is

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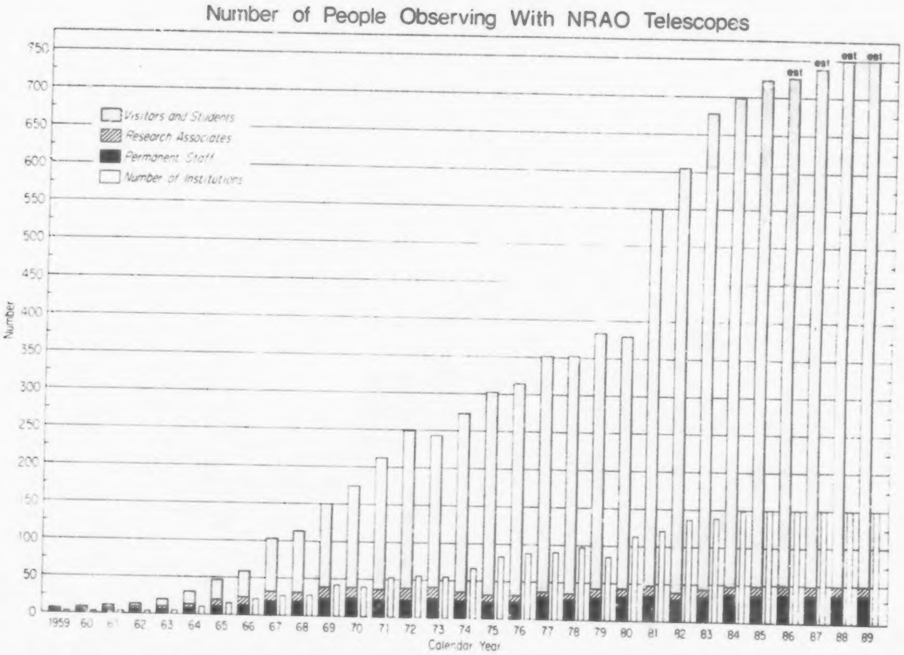


Figure 1. This bar chart shows for each calendar year the number of NRAO permanent research staff and the number of research associates who use the telescopes. In addition, it shows the total number of visitor-users of NRAO telescopes and the number of institutions from which the NRAO visitors come. The significant jump in these last two categories for 1981 reflects the increased use of the VLA.

rapidly growing to accommodate new observers from the optical, infrared, X-ray, and related areas.

The NRAO Student Program is illustrated in Figure 2. The vast majority of the student users are graduate students from universities having Ph.D. programs in astronomy. A large increase in graduate student users occurred when the VLA began operations. As with the other categories of users, this increase is due not only to the research opportunities the VLA presents but also to the accessibility to this instrument made possible by the Observatory staff.

The Summer Student and Co-op Programs are a much smaller component of student usage of NRAO facilities, but these are important in the national programs. Both serve to introduce senior undergraduate and beginning graduate students to radio astronomy. The Summer Student Program focuses on astronomical research; the Co-op Program is conducted with university groups of engineers, applied physicists, and computer scientists. Both are important mechanisms for acquainting skilled scientists with issues of importance to the field of radio astronomy.

The extent to which NRAO is dedicated to its user community can be seen by examining Figures 3 and 4. Approximately 35,000 observing hours exist in principle in one year for all four of NRAO's telescopes taken together (4x24x365). The actual hours scheduled for observing with these telescopes are shown in Figure 3, where the recent totals are approximately 30,000, or 86%. The remaining 14% is scheduled for

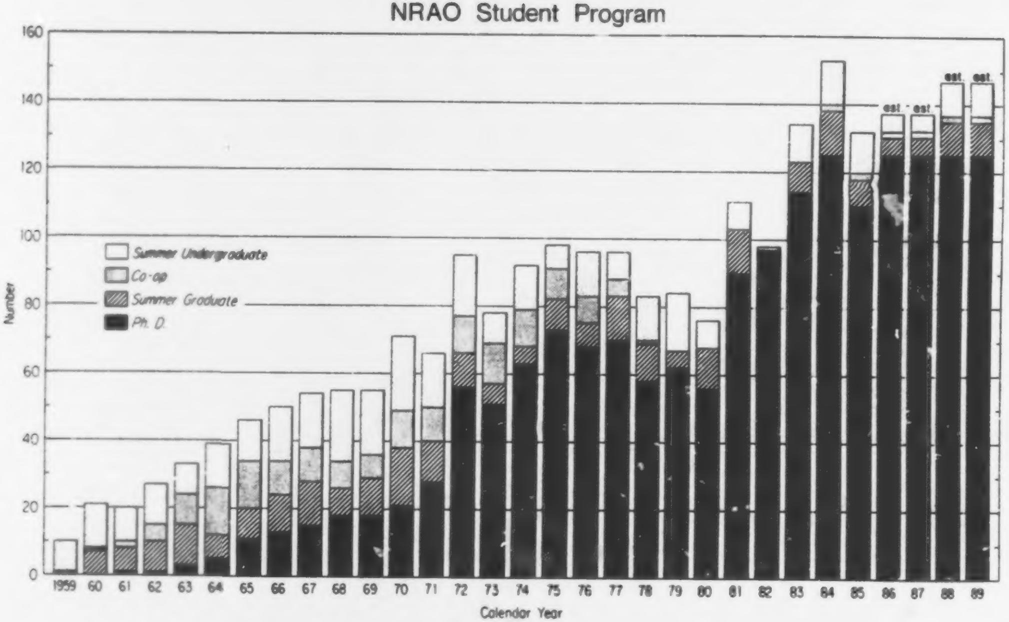


Figure 2. This figure shows for each calendar year the number of Ph.D. students (salaried and non-salaried), co-op students, and summer undergraduate and graduate students who observed or worked at the NRAO during that year.

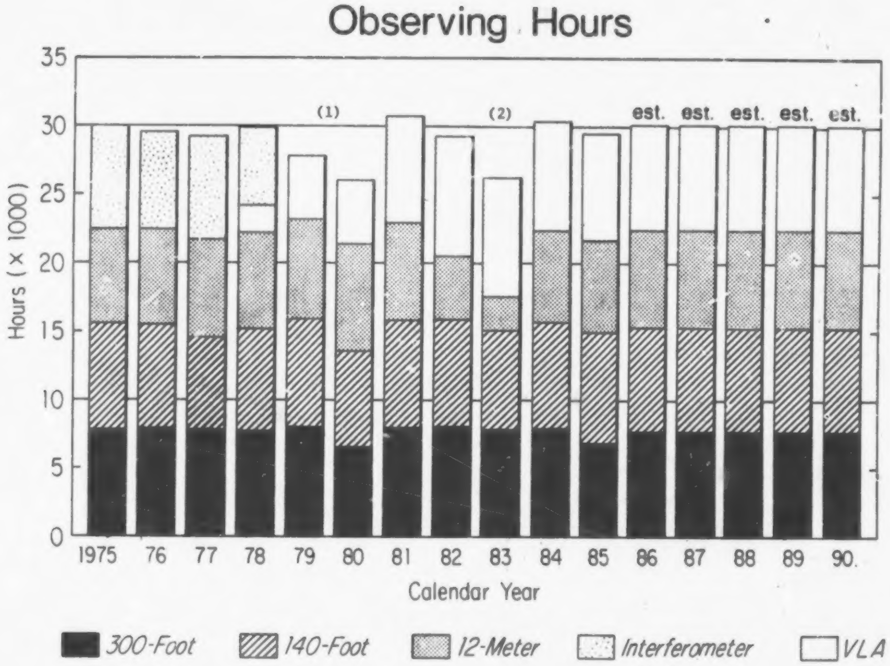


Figure 3. Hours scheduled for observing on each telescope during the last decade.

(1) Shutdown of observing on 3-element Interferometer and commissioning of the VLA.

(2) Resurfacing of the 12-meter millimeter wave telescope.

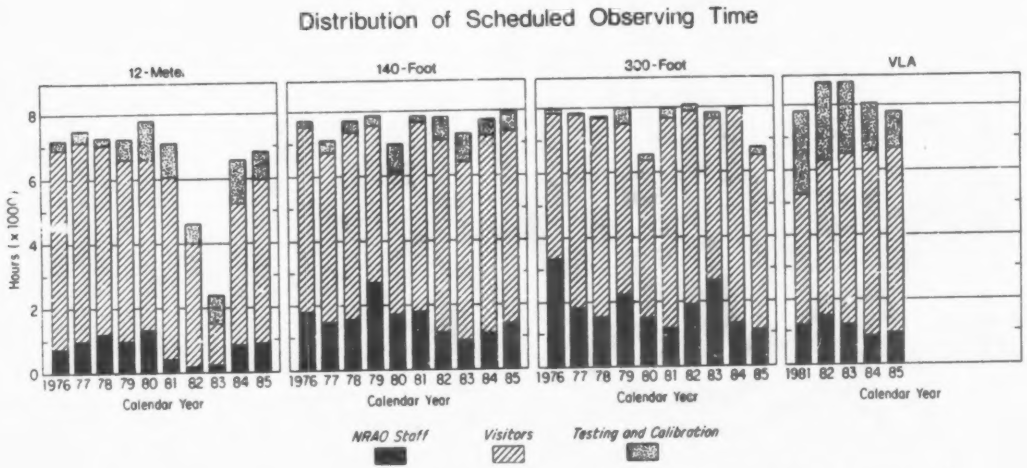


Figure 4. These graphs show the number of hours scheduled for calibration and for observing by the NRAO staff and by visitors on each telescope system during the last decade.

tests, calibration, preventative maintenance, installation of new equipment, and repairs.

The only periods when less than about 85% of the available time was scheduled for observing was in 1979-80 after the three-element interferometer was closed and before the VLA began full operation, and in 1982-83 when the 36-foot millimeter-wave telescope was re-surfaced and re-christened as the 12-meter telescope. The telescopes, which operate 24 hours a day, are efficiently scheduled to produce as much observing as possible.

How is the observing time allocated to staff and visitor users? Different projects require differing amounts of time, but all grants of observing time are made on the basis of scientific merit. Proposals are refereed and graded for merit by anonymous referees selected from the community. The detailed scheduling is done by the site directors, with the assistance of a special committee in the case of the VLA. The rule that observatory staff compete for time on the same footing as visitors is fundamental and has contributed a great deal to the excellent relationship between the Observatory and its user community.

Figure 4 shows the actual observing time distribution among NRAO scientific staff, visitors, and calibration and test time. Over time, the NRAO staff has qualified to utilize about 15% of the observing time, with some variation from telescope to telescope. This level of use is judged to be adequate to enable the Observatory staff to maintain a competitive research program of its own, which is necessary if the Observatory is to continue to provide effective leadership within the U.S. radio astronomy community.

STAFF AND OPERATIONS

The growth of NRAO's permanent full-time staff over the history of the Observatory is shown in Figure 5. The steady, smooth growth up to 1970 accompanied the construction of the 300-foot, 140-foot, millimeter-wave, and three element interferometer. The size of the operations staff was constant throughout most of the VLA construction period and increased in response to major new user requirements as operation of that instrument began in 1979. Current fluctuations reflect uncertainties in budget levels. Personnel levels throughout the VLBA construction period are expected to follow the VLA pattern; additional staff will certainly be required if this major new facility is to be operated efficiently at its completion.

It should be noted that following full operation of the VLA the number of NRAO users doubled (100%) and is still increasing as is the number of student users, but the increase in staff to serve these users was only 25%.

The composition of the scientific staff at NRAO is given in Table 1, where the scientific staff is defined as all professional employees holding a Ph.D degree. The total Ph.D. staff is 70 employees, 19% of all full-time permanent employees. Of these 70, 30 form the basic research staff, or 8% of all full-time permanent employees. Twenty of the 70 members of the Ph.D. staff hold tenured positions, or 5% of the

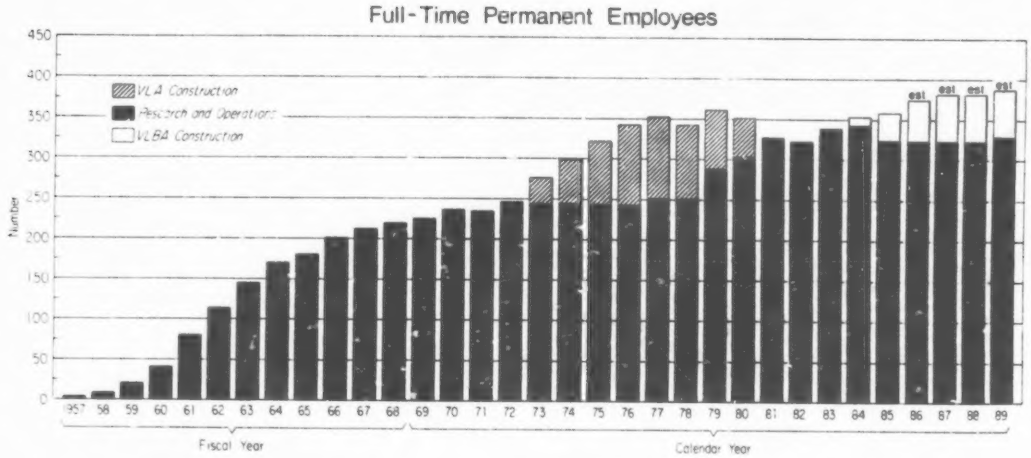


Figure 5. This figure shows the total number of NRAO full-time, permanent employees at the end of each year, projected into the future.

Table 1

National Radio Astronomy Observatory

Ph.D. Staff Classification/Distribution

Basic Research Staff	Other Ph.D. Staff
30 Total	40 Total
8 Postdoctorals	13 Operations/Management
2 Assistant Scientists	9 Electronics
4 Associate Scientists	8 Computing
12 Scientists	8 VLBA Project
4 Senior Scientists	
—	—
30	40
15 Term Appointments	29 Term Appointments
12 Tenured	8 Tenured
3 Visiting	3 Visiting
—	—
30	40

Total Full-Time Employees			366
(including construction projects [48] and Navy time-keeping operations [10])			
Total Ph.D. Staff		70	19%
Total Tenured Staff	20	29%	5%

staff. These numbers are consistent with the original intention that the Observatory have a small, dedicated research and development staff.

BUDGETS

The history of the NRAO budget for operations and equipment (excluding budgets for construction, e.g., VLA and VLBA construction) is shown in Figure 6. The annual budgets are shown in actual, current dollars in millions. The Consumer Price Index is also plotted for these years, with an estimated extrapolation to 1986 and 1987 of 4% each year. The extent to which budgets have simply tracked inflation, as defined by the CPI, is noteworthy. For more than a decade NRAO has had an essentially level budget, after correction for inflation, despite the addition of a major new telescope which doubled the number of users and required a 25% increase in staff.

How has this increase in operational requirements been accomplished within the constraint of a constant and now declining budget? What has been the impact upon the Observatory functions and operations? The salary structure has been affected, particularly in areas of engineering, advanced electronics design, and computing. Lack of competitiveness in such activities is a major concern for the long-term health of the Observatory. Capital equipment needs for both research and for development programs must be curtailed or deferred. Figure 7 shows the profile of such expenditures in constant 1985 dollars; the current year dollars for the earlier years are much lower, of course. Major computing needs, both for Observatory operations and

Operations & Equipment Budget Compared With The Consumer Price Index Curve

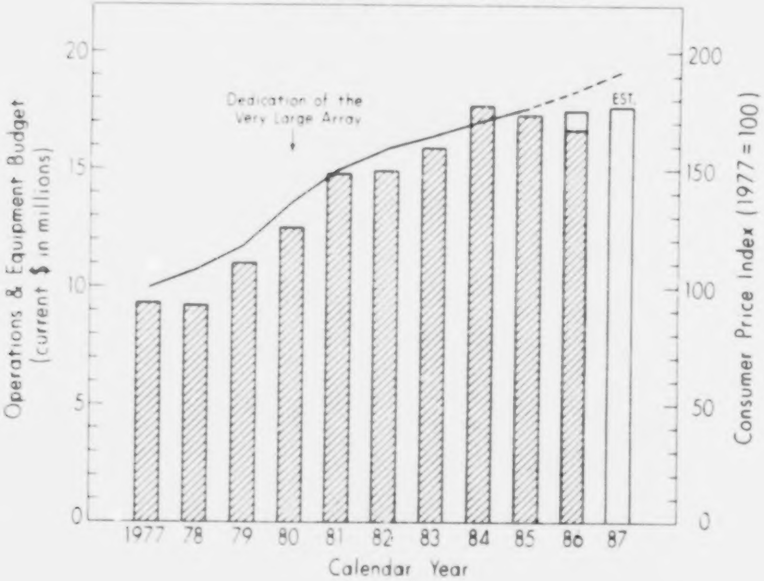
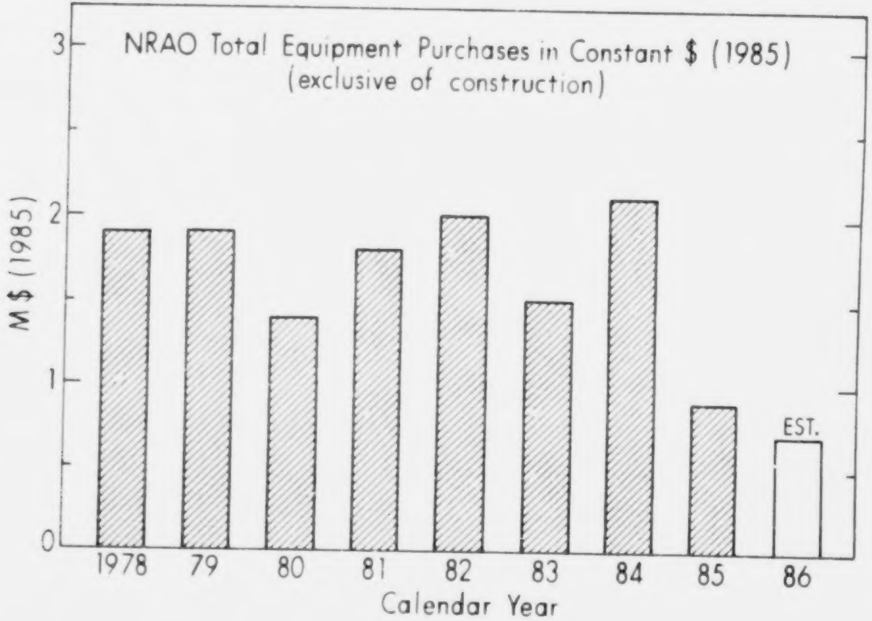


Figure 6.



NRAO Total Equipment Purchases in Constant $ (1985)
(exclusive of construction)

Figure 7.

for enormously increased user requirements, have also been met only in part. The level of service that the Observatory has been able to provide to the user community at many of the telescope sites has necessarily been cut back. Finally, it is increasingly difficult for the Observatory to provide the resources required for the development of new state-of-the-art electronic receiver systems, computer software, and new visionary telescopes of the future. Nevertheless, within the framework of its budget structure, the NRAO remains a vital and productive institution.

February 1986

Responses to Specific Questions

1. **Please provide for the record a brief summary of:**

   a. **the percent of the consortium's total budget provided by NSF:**

   In FY 1985, AUI received a management fee of $345,000 from NSF for the management and operation of NRAO. At the same time, it received $1,100,000 from DOE for the management of BNL. Total FY 1985 expenses from NSF were $20,444,000; thus, the management fee was 1.6% of the total.

   b. **the portion of the consortium's management or consultant fee received from NSF, compared to funds for research, and for facility maintenance and upgrade;**

   The management fee received from NSF for the operation of NRAO is negotiated on the basis of the annual corporate expenses dedicated to the management and operation of the Observatory at corporate headquarters and the several sites. It provides for prorated expenses, associated with NRAO, of the Board of Trustees, corporate management, legal, financial, audit and related functions. Moreover, approximately one-third of the fee is budgeted for activities directly related to NRAO that are appropriate to good management of a scientific institution but, for various reasons, not directly reimbursable under the contract. The latter functions include Visiting Committees, lectureships, Trustee scholarships for employee families, visitor transportation, local community activities, etc. All funding for research, construction and maintenance is directly reimbursed and is provided for within the contract itself on an annual basis.

   c. **the portion of the consortium's funds allocated for overhead and what that overhead includes;**

   The annual management fee, negotiated as described above, covers all management expense. AUI does not receive any overhead fee as such.

   d. **the membership fee the consortium charges to participating universities and how the fee is utilized by the consortium;**

   AUI is not a membership organization or a consortium. It receives no fees from any outside institution.

   e. **How are the consortium facilities managed to assure the equipment, instrumentation and bricks and mortar are maintained and properly renovated? Do the centers include a separate line item for this end of operations?**

   The Director of NRAO has the prime responsibility of presenting

The need for large centralized research facilities varies greatly from field to field. High energy physics is almost totally dependent upon large accelerators and nuclear physics is moving rapidly in the same direction. Astronomy has been revolutionized by the new technologies that reside in the great modern telescopes and National Centers. Similarly, earth, ocean and atmospheric sciences have entered a new era of major coordinated programs. There are other communities like materials science, solid state physics, chemistry and biology that still rely predominately upon large numbers of single investigators and small groups. Even in such fields there is a growing awareness of the power and unique capabilities of large centralized facilities such as the National Synchrotron Light Source.

Each field of science has its own internal dynamics and its own range of opportunities and priorities. In considering the question of the balance between centralized facilities of all sizes and individual investigator groups there is almost unanimous agreement on one point, namely, that the long-term health of the science depends most critically upon the vitality and stability of the university investigator groups. They provide the critical ingredient for all future progress – the students. How then is balance to be maintained when new opportunities for truly innovative and productive facilities arise?

There is no simple-minded prescription that fits all areas. Each field has a different balance and, history tells us, these balances do change slowly with time. Sensible policy requires that each community debate its priorities in many public, representative forums and structure its plans so as to maintain an appropriate balance.

There is no doubt that, in all fields, there will be increasing dependence upon sophisticated facilities of all sizes and difficult decisions must be made. Unfortunately, such debates are often noisy, with dissent on both sides, but consensus can be reached. In the field of ground based astronomy, supported by the NSF, the research community has, indeed, done this successfully.

4. **What is the role of the consortium, versus the director of the national facility managed by the consortium, in setting research priorities, budget levels, personnel ceilings and salaries for the national facility?**

This question is addressed above in the description of the structure and operation of AUI.

5. **As international participation in your research activities increases, are new problems created, (for example: obtaining permission to conduct research in the "exclusive economic zone"; political issues which could destabilize the support of the program; and intellectual partnership and scientific exchange)?**

The need for large centralized research facilities varies greatly from field to field. High energy physics is almost totally dependent upon large accelerators and nuclear physics is moving rapidly in the same direction. Astronomy has been revolutionized by the new technologies that reside in the great modern telescopes and National Centers. Similarly, earth, ocean and atmospheric sciences have entered a new era of major coordinated programs. There are other communities like materials science, solid state physics, chemistry and biology that still rely predominately upon large numbers of single investigators and small groups. Even in such fields there is a growing awareness of the power and unique capabilities of large centralized facilities such as the National Synchrotron Light Source.

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5. **As international participation in your research activities increases, are new problems created, (for example: obtaining permission to conduct research in the "exclusive economic zone"; political issues which could destabilize the support of the program; and intellectual partnership and scientific exchange)?**

How do you prepare for sustained international program support, and what is the consortium's role versus NSF's role in this regard? How do you plan to involve additional nations in the cost-sharing of your international science programs?

NRAO facilities are open to the scientific community on a competitive, meritorious basis. In this process, foreign nationals from world observatories do have the opportunity to use the facilities. By the same token, NRAO and other U.S. astronomers compete for and are awarded time on many foreign telescopes. This results in a great deal of intellectual exchange and co-publishing of results and is judged to be healthy for the science.

NRAO does not have any joint installations or institutional support programs with foreign observatories. There is, however, a great deal of exchange of technology and instrument specifications that makes it possible for U.S. telescopes to be used in an interferometric VLB mode with foreign telescopes. NRAO plays a leading role in coordinating the technology that makes this possible. This effort will become increasingly important as a worldwide VLBI network is established. Similarly, in the long-term, a space arm of the VLBA will require a much more organized international effort for successful and efficient operation.

6. **Does your organization purchase insurance for reimbursement of loss, damage, or penalty (indemnification)? What is the cost of this insurance and what level of protection is provided by insurance you purchase? Who would pay damages not covered by the insurance or if insurance protection levels are exceeded? Do you have recommendations on how indemnification should be addressed by the government?**

AUI maintains insurance for workers' compensation, employer's liability, comprehensive general liability (bodily injury and property damage) and comprehensive automobile liability (bodily injury and property damage) with respect to performance under the NSF contract. The limits of coverage are consistent with state and local laws where the Observatory facilities are located. The 1986 annual premium cost for these policies is about $82,000. It should be noted that, consistent with the government's self-insurance policy, government-owned equipment and property is not privately insured.

Following elimination of the "hold harmless" provision by NSF from the AUI contract January 1, 1984, AUI obtained additional insurance to provide limited protection from risks not otherwise covered and from potential claims in excess of the limits contained in the basic policies. Because of recent national problems in the insurance industry, available limits of liability coverage are being reduced and rates for insurance that is available are being drastically increased. For example, the Umbrella

Liability policy coverage of $25,000,000 obtained in 1984 has been recently reduced by the carrier to $20,000,000 with a significant increase in total premium cost. Similarly, available coverage for Professional Liability (Errors and Omissions) has all but been eliminated, that is, involuntarily reduced from $10,000,000 to $1,000,000 with related premium costs increasing disproportionately. A third policy covering Officers' and Directors' Liability ($10,000,000) is not now up for renegotiation, but a change for 1987 can certainly be anticipated. The present annual cost of these policies is $30,000.

The present contract does not explicitly protect the contractor in the event that awards exceed the levels of coverage or for claims that are made for matters for which no commercial coverage is available such as is true in the environmental area. The contract states:..."In the event the Contractor incurs liabilities to third persons in the performance of this contract other than through loss or damage to property or for death or bodily injury not compensated by insurance or otherwise, NSF shall make good faith efforts to provide or obtain relief, including good faith efforts to obtain the obligation of additional funds hereunder. The Director of the Foundation, in his or her sole discretion, shall determine the appropriateness of reimbursement of the Contractor for any loss as provided for in the preceding sentence..."

For contracts like those covering Center operations by non-profit organizations having modest, if any, resources of their own, a "hold harmless" type of indemnity, such as existed in the AUI contract for over twenty-five years, would in our judgment be the best arrangement. This would provide protection by the government from an extraordinary award that might result from an accident or from "Errors or Omissions" in the normal course of work performance. It must be understood that the "hold harmless" concept does not provide protection for the contractor from acts of willful misconduct or lack of good faith on the part of the Trustees, officers or senior managers. Thus, the overall risk to the government is extremely low, but the penalty to the contractor in the event of such an extraordinary award would be very high. Even with bankruptcy and possible suits against Trustees (or member institutions in the case of a consortium) the liability might still not be met, and this is not in the public interest. Moreover, even though this is an improbable outcome, it is a level of risk that individual Trustees, working without recompense, should not be expected to assume. In the final analysis, it should be noted that the government always has the right of contract termination, and performance by a contractor resulting in exposure of the government to unacceptable financial risks would surely be considered as a cause for termination.

7. **What effort do you make to increase the number of universities which are members of your consortium? What is being done to assure that talent in non-member universities is involved in the consortium research planning and priorities?**

Although AUI is not a membership organization, a great deal of effort is expended to ensure that input into research planning and priorities is obtained from the entire astronomy community. This is achieved by appropriate selection of Trustees from active institutions, by careful structuring of the Visiting Committee for NRAO and through numerous advisory committees, working groups and users groups. All plans and priorities are also discussed with NSF and with the broadly based NSF Astronomy Advisory Committee.

8. **Is your contract with the National Science Foundation clear as to what the consortium manages, how and what the lab or project director manages, and what the responsibilities are of the NSF and National Science Board? Please describe policies and criteria which clarify these responsibilities.**

The contract between the NSF and AUI for the management and operation of NRAO has been in force for some thirty years. Over this time, experience under the contract and mutually agreed upon refinements have created an understanding of the responsibilities and policy structure of AUI that is well understood by all parties. Details are imbedded in the contract itself and in the AUI Organizational and Policy Manual. While minor issues occasionally arise and are quickly settled at the day-to-day operational level, AUI has no serious concerns over the execution of the rights and responsibilities of the NSF in monitoring this contract in the public interest.

AUI and NRAO policies and responsibilities are outlined in the two brief profiles accompanying this response.

Questions for Dr. Hughes
on the National Radio Astronomy Observatory (NRAO)

1. **Annual funding for construction of the Very Long Baseline Array (VLBA) Radiotelescope System has been less than originally planned. NSF now intends to extend the construction period.**

   What are the consequences of the "stretch-out" in construction of the VLBA? How would this affect the astronomy research community and the other radiotelescope facilities operated by the National Optical Astronomy Observatories (NOAO)? Have these delays effectively increased the cost of the VLBA?

   As developed over a planning period of many years, the VLBA was structured as a $60 M project, with a three-year construction period starting in 1985. Later, this had to be revised to four years at $15 M each. For the first year of construction (1985), $9 M was available. For 1986 only $8.6 M is available, following a G-R-H cut. The 1987 agency request is for $9.4 M. Project plans have been developed that would make it possible to complete construction over a number of different schedules. For example, if full funding is completed in 1991 the project would go on line in 1992 at a total cost in excess of $80 M. The cost increase in all cases is entirely due to the stretch-out.

   The impact of the stretched-out construction extends beyond cost considerations. The scientific impact of the VLBA will be gradual as antennas are added and then brought to a fully instrumented state. The existing VLBA community must be maintained throughout this period while working with less than fully effective systems. The strain on existing NRAO operations from any major construction project is considerable. VLBA is not an exception. There will be a longer period during which normal operations are compromised. The U.S. is expected to play a leadership role in the development of worldwide very long baseline interferometry. Delay of the VLBA completion makes it more difficult to do that. VLBA has had a long record of review at all levels, with ringing endorsements from the astronomical community and the National Academy of Sciences. The credibility of an orderly review and priority process would be brought into question if there are extraordinary delays in the timely completion of this very high priority project.

2. **The Very Long Baseline Array System is to be composed of ten individual radiofrequency antennas distributed geographically from Hawaii to Puerty Rico.**

   What are the consequences of starting the VLBA operations with less than ten antennas?

   It has always been planned to begin preliminary operations as soon as the first antenna is completed. We anticipate an evolution from a state in which the first VLBA antennas participate in the ongoing program of observations with the ad hoc network of telescopes that are currently available from time to time for Very Long Baseline Interferometry (VLBI) to a state in which such observing programs are dominated by the VLBA. The interim science will be useful to test elements of the VLBA system during construction, but its intrinsic value will be somewhat limited by incomplete compatibility of the partial system with older, less versatile antennas. The VLBA, like any other complex instrument, is severely compromised by the absence of any of its parts, and its full power and impact will not be realized until all ten antennas and associated instrumentation are complete. For example, the dynamic range and resolving power will be more than doubled with the addition of the three final antennas.

3. **In your testimony you refer to major computing needs, both for observatory operations and for user data processing requirements.**

How are the computing needs at NRAO currently being met? In particular, do you need large-scale computing (supercomputer) capabilities?

The computing needs at NRAO are dominated by the need to create and process radio astronomical images from the data produced by the Very Large Array (VLA). This need has grown enormously due to a number of factors:

- The sensitivity of the VLA has been steadily improved by significant new advances in receiver technology and many observations require far less observing time than was originally contemplated;
- New computer algorithms have been developed that allow instrumental and atmospheric effects to be removed from maps and greatly reduce observing time requirements, but only at the cost of vastly increased computing; and
- It has been possible to develop receivers and systems that provide for operation in a spectral line mode which produces important new data but at a much higher rate.

Overall, the available data rate has increased one hundred fold and modern algorithms can require one hundred times as much computation to obtain incredibly high-resolution images. This factor of 100x100 = 10,000 in requirements is well beyond the reach of our current capabilities.

NRAO has responded to this shortage by restricting high data-rate experiments on the VLA and by developing and supporting image-processing software that can be run on computers at user institutions. The latter effort has approximately doubled our output but it still falls far short of the true needs.

Large-scale computing capability is required. NRAO has been utilizing the NSF Supercomputer Access Program to develop the necessary software and to process some of the highest priority large-scale projects that cannot otherwise be done. The best solution to the computing needs is for NRAO to acquire its own supercomputer. A detailed description of the system required has been fully formulated.

4. **In your testimony you point out that for more than a decade, NRAO has put a strain on observatory operations, capital equipment and staff.**

Do you envision the necessity to shut down lower priority telescope facilities in favor of operations at the high priority facilities? Have you begun to plan for this possibility?

A history of level (constant dollar) budgets followed by the very restricted budget for 1986 has forced the Observatory to defer major maintenance and instrumentation development, to cut back postdoctoral and student programs, to restrict user services to limit Observatory activities to those essential for telescope operations, and to cut personnel levels. A 1987 budget level with 1986, or reduced from 1986, would force additional measures that would be harmful to the future vitality of the Observatory. Resultant inefficiencies in operation would be difficult to justify over the long-term without considering drastic alternatives. The question of closing even a productive, forefront facility would be difficult to avoid under such circumstances. The Observatory regards the question of facility closing as one requiring careful review, within the Observatory, by AUI, by NSF, and by the entire astronomical community. No formal plans for such action have yet been structured, but with the cooperation of the Visiting Committee, Advisory Committees, User Groups and the NSF Advisory Committee, the scientific productivity and merit of the Observatory programs is continuously assessed.

5. **Since its inception, the Committee on Science and Technology has strongly supported the eventual construction of the VLBA. In addition, the National Academy of Sciences has cited the VLBA as one of the most critically important projects to continue effective progress in astronomical research in the 1980's.**

The VLBA has a long history of review and endorsement. In the light of early experiments in the preceding seven years, the Greenstein Report in 1972 cited a dedicated VLBI array as part of the "Vision of the Future." Following ten more years of experimentation and design studies by NRAO and the VLBI community, principally the Caltech and MIT groups, the NSF Astronomy Advisory Panel endorsed the VLBA as a 1984 new start. Also in 1982, the NAS/OSTP Astronomy Briefing Panel identified the VLBA as a "high leverage project" for a 1984 start. That year a formal proposal to build the VLBA was submitted to NSF by NRAO. The Field Committee of the NAS also endorsed the VLBA in 1982 as the highest priority new start for ground based astronomy. A NAS workshop in 1983 identified the multidisciplinary importance of the VLBA. The NSF Astronomy Panel has repeatedly endorsed VLBA as the top priority for the NSF astronomy program. This construction project is the culmination of a long process of development and careful review and should be funded for timely and efficient completion.

Mr. WALGREN. Thank you very much, Dr. Hughes.

Dr. Teem.

Dr. TEEM. Thank you, Mr. Chairman, and members of the committee. I appreciate your invitation to testify before this subcommittee in my capacity as president of the Association of Universities for Research in Astronomy by participating on this panel.

At this time, as you have suggested, I would like to submit my formal prepared statement to the reporter before I go on to summarize briefly certain of its contents.

The Association of Universities for Research in Astronomy, which we often refer to as AURA, a not-for-profit corporation, is a consortium of 17 member universities. Each of these universities, which are identified in the appendix to my testimony, has a commitment to significant educational and research programs in the astronomical sciences. All are also dedicated to the concept of national observatories which provide access to first-class astronomical facilities for all astronomers, based solely on the scientific merit of their proposed use, as judged by their peers.

AURA operates such major astronomical centers for two Federal agencies. The first of these—under contract with the National Science Foundation—is the National Optical Astronomy Observatories, abbreviated NOAO. The second—under contract with NASA—is the Space Telescope Science Institute, which will provide science operations for the Hubble Space Telescope, after its launch.

However, I should confine my testimony to matters pertaining to AURA's responsibilities for the NOAO and NOAO's role in the NSF astronomical sciences program.

The NOAO combines in a single organization the NSF's national observing facilities for both visible and infrared wavelengths. It provides 20 such observing facilities located at observatories in both the Northern and Southern Hemispheres. Its observing sites on Cerro Tololo, which is in the Andean foothills, about 300 miles north of Santiago, Chile; Kitt Peak, about 65 miles southwest of Tucson, AZ; and Sacramento Peak, about 35 miles up the road from Alamagordo, NM. Base facilities for computers, laboratories, offices, and so forth, are located at Tucson, AZ, and La Serena, Chile.

Access to such facilities is the only way that astronomers lacking first-class optical telescopes at their own institutions, either because of their geographic location or limited resources, are able to carry out competitive research.

NOAO's facilities are described in my submitted testimony.

The NOAO staff numbers about 450 at present, of which approximately 12 percent are astronomers. In addition to assisting visiting observers, NOAO staff scientists carry out research in their own right and provide the intellectual leadership for improving and extending its instrumental capabilities.

Approximately 20 percent of observing time on any NOAO facility is currently used by the NOAO staff astronomers who compete for it on the same basis as all others.

Mr. Chairman, I just wish that time permitted my discussing the very exciting research that is produced by visiting astronomers and staff scientists using these facilities.

I do not believe there has ever been a time in the history of astronomy when the pace and quality of discovery has been as great as now, but due to the time limitations and the fact that the focus of this hearing is on the fiscal year 1987 NSF budget, I will discuss only these other topics.

I want to start by adopting a somewhat different approach than what my other colleagues have. I start by giving a graphic perspective on the NOAO budget, using the first chart. This chart is also in my testimony. Functional categories of expenses and their current share of the NOAO budget are summarized there. The largest part is devoted to operations and maintenance—on the right—of existing observing facilities at the three sites. This, together with the scientific operations slice, at the bottom of the chart, provide the resources for operating current facilities.

Future improvements, both new instruments for existing facilities and technology enabling radically improved facilities, is a focus of the projects category at the upper left of the chart.

A key NOAO program of the latter type is the new telescope technology, or NTT program. You will note from the displaced slice, at the top, that a substantial portion of that program's budget is external, subcontracted efforts at cooperating universities, principally to the University of Arizona at this time. This effort is under overall program management by NOAO and is discussed in more detail in my testimony.

I have discussed this program and would encourage any questions at the end, if you wish.

The last budget category, management and administrative support operations, will probably be budgeted indirectly as overhead at most institutions. It amounts to about 25 percent of the total.

Before discussing the adequacy of the fiscal year 1987 budget, Mr. Chairman, I would like to look back at some trends in the NOAO budget over the past decade. It is important to consider not only the funds obligated to NOAO year by year, but also the purchasing power of these funds in constant value dollars.

I have estimated this purchasing power by applying standard methods of deflating current budgets, expressing them in constant value fiscal year 1977 dollars. The result is shown in my next chart.

These NOAO—I call them deflated budgets—are plotted in two forms: the black data at the top show total NSF funds allocated to NOAO, while the lower data show the in-house NOAO funds only. The basic trends are obvious: a relatively flat plateau in the late 1970's, a slide to a minimum in 1982, followed by recovery over 2 years, and a relatively flat value from 1984 through 1986, which is also projected to continue next year if the value in the fiscal year 1987 budget request is appropriated.

I ask myself: if this is so, why have we been having so much difficulty in maintaining all of the roles in the NSF Program for NOAO in recent years, compared, at least, to the level for the 1970's.

Since the slide in the 1980's began, there has been great pressures by AURA on NOAO management and on AURA, itself, to improve efficiency of NOAO operations, while maintaining their effectiveness.

Much good has come of this, and real improvements have been made. But it is becoming increasingly clear that it may be impossible to continue to carry out effectively all past programs and services in the future.

I believe there are two reasons for this state of affairs, Mr. Chairman.

The first is illustrated by the lower branch of this chart. The in-house funds available drop by about 5 percent from the 1970's period, as NOAO subcontracting has increased.

The next chart illustrates a second reason. The cost of NOAO operations are approximately 65 to 70 percent personnel-related. When the in-house NOAO budgets are compared year by year with the personnel levels of NOAO, as is shown in this chart, it is clear that the impact of inflation on NOAO operations is not adequately estimated, using the generally accepted inflation indices.

You notice that although the constant dollar budget level of the NSF effort is down only 5 percent, reductions in the number of personnel, by 25 percent, have been necessary over this time period.

Since AURA wage and salary scales have not increased significantly more rapidly than the consumer indices, an additional deflation or loss of purchasing power of about 20 percent over the past decade has been experienced.

In my opinion, this is due to the increasing technological complexity of the astronomical research facilities.

Thus, what at first sight appeared to be a reasonably constant level of support for NOAO, ignoring the dip around 1982 for the moment, is, understandably, a significantly constraining financial situation.

I believe this type of problem is shared by most other research institutions.

Well, these NOAO budget trends have not taken into account the potential impact of the Gramm-Rudman-Hollings Act sequestration. An attempt to estimate this is shown in my last chart, which is comparable to the second one I showed.

The assumptions made in this particular projection are discussed in my submitted testimony.

As will be expected, the budget trend lines since 1984 in this case decreased at a more significant rate, with purchasing power declining approximately 4 percent per year in this last period.

Note that the level of in-house NOAO budget would drop to almost as low as it was at the fiscal year 1982 minimum.

We have not had time, Mr. Chairman, to evaluate using AURA's structure of review and advisory committees, which are very similar to those discussed by my colleagues, and to analyze the programmatic impact on NOAO of the recommended fiscal year 1987 budget, either with or without sequestration, in sufficient detail to discuss them here.

However, it is clear that we must consider all possible options to maximize NOAO's ability to carry out its role in the overall NSF Program, while attempting to run a viable observatory program at reduced purchasing power.

Recognizing the national need for budget constraint, I urge you to see to the authorization of the President's fiscal year 1987 NSF budget and to encourage your colleagues to appropriate funds at the recommended budgetary level.

Frankly, however, Mr. Chairman, I do have some concerns about the adequacy of these resources to support maximum utilization of these facilities, which was a question you raised in your letter of invitation.

These concerns are discussed more fully in my prepared statement, but I shall try to summarize them very briefly now.

First, what is certain is that utilization of the NOAO facilities will not be maximal. NOAO has had to change the scheduling patterns on telescopes to minimize instrumental changes and mothball three nighttime telescopes and plans to shut down all but the largest telescopes at some times during the year in order to optimize the use of a reduced staff for preventive maintenance.

Generally speaking, the new scheduling approach will result in fewer users of the facilities, although the scientific impact of this change will be offset to some degree by longer average runs.

Second, the solar observing facilities at both Sacramento Peak and Kitt Peak are operating with a reduced staff, effectively, but far from maximally. In my prepared statement I discuss the status of priorities among NSO facilities and AURA's intent to work toward the healthy operation of these facilities, both on Sacramento and Kitt Peaks in fiscal year 1986 and in future years.

Regarding the adequacy of resources to improve NOAO's capabilities for research, Mr. Chairman, as I noted earlier, such efforts are encompassed in the NOAO project category. As I mentioned, the costs of new instruments for the existing telescopes are increasing due to technological complexity.

Personnel resources for such improvements are down significantly from 10 or even 5 years ago; however, while many proposed instrumentation projects have to be rejected, we are maintaining an excellent set of instrumentation and within the resources available will continue to devote an appropriate share of the resources available to this area.

For solar observing, for example, the program of facility improvement of the Sacramento Peak vacuum tower telescope continues, and we are also gratified that the NSF and its peer review panels have given encouragement to NOAO to establish a network of automated solar observing stations around the world to study with higher resolution than single stations can the so-called global oscillations of the Sun.

Mr. Chairman, you also invited me to comment on any other issues that I wished to bring to your attention.

I have gone on for about 13 minutes now, and I can avoid that if you wish.

Mr. WALGREN. Well, I think in the interest of time, I think we ought to bring the whole thing to somewhat of a close, but let me recognize Mr. Boehlert.

[The prepared statement of Dr. Teem and answers supplied to questions for the record follow:]

Testimony of
Dr. John M. Teem, President
Association of Universities for Research in Astronomy, Inc.
before the
Science, Research and Technology Subcommittee of the
House Committee on Science and Technology
February 25, 1986

Mr. Chairman and Members of the Committee:

I appreciate your invitation to testify before this Subcommittee, participating in this panel of presidents of managing consortia for NSF large-scale research facilities.

The Association of Universities for Research in Astronomy, which we often refer to as AURA, a not-for-profit corporation, is a consortium of 17 member universities. Each of these universities, which are identified in the Appendix to my testimony, has a commitment to significant educational and research programs in the astronomical sciences. All are also dedicated to the concept of National Observatories which provide access to first-class astronomical facilities for users, based solely on the scientific merit of their proposed use, as judged by their peers.

AURA operates such major astronomical centers for two federal agencies. The first of these--under contract with the National Science Foundation-- is the National Optical Astronomy Observatories (abreviated NOAO). The second --under contract with NASA--is the Space Telescope Science Institute, which will provide science operations for the Hubble Space Telescope, after its launch. Because the focus of the Committee's hearings today is the NSF's programs, rather than NASA's, I shall confine most of my testimony to matters pertaining to AURA's management responsiblities for the NOAO and NOAO's role in the NSF Astronomical Sciences program.

NOAO Program and Budget Structure

NOAO plays four principal roles in advancing astronomy within the NSF's program. These are:

a. Providing and operating state-of-art ground-based observing facilities which are made available--within the time available--to astronomers with the most meritorious proposals.
b. Developing innovative instrumentation and advancing technology for optical/IR telescopes.
c. Carrying out frontier research in the astronomical sciences (by NOAO staff scientists).

d. Developing concepts and technologies for innovative frontier telescope facilities and, when approved by NSF and funded by Congress, building such facilitities and operating them for use by the broad community of astronomers.

The NOAO combines in a single organization the NSF's national observing facilities for both visible and infrared wavelengths, supporting night-time observations of stars and galaxies and day-time studies of the sun. NOAO provides twenty such observing facilities at three sites, including major observatories in both northern and southern hemispheres, and also operates two base facilities (for offices, shops, libraries, etc). Its observing sites are on Cerro Tololo (located in the Andean foothills about 300 miles north of Santiago, Chile), Kitt Peak (about 65 miles southwest of Tucson, AZ), and Sacramento Peak (about 35 miles up the road from Alamagordo, NM). The base facilities are located at Tucson, AZ and La Serena, Chile.

A major portion of the astronomical research, carried out in this region of the spectrum, which is reported in US journals each year is based on observations made at NOAO. Last year, more than 875 visiting astronomers made observations with NOAO facilities. Access to such facilities is the only way that those astronomers who do not, either by virtue of their location or resources have first-class optical telescopes at their own institutions, are able to carry out competitive research.

Thirteen of the NOAO telescopes, including two of four-meter diameter, one in each hemisphere, are used primarily for night-time observations at Cerro Tololo or Kitt Peak, and seven are used primarily in the daytime for solar observations, either at Kitt Peak or Sacramento Peak. However, certain of the "night-time" facilities are used in the daytime for observations of bright infrared sources. The remaining telescopes include three with apertures greater than 1 meter, and some of the best instrumented one-meter size telescopes currently in operation. Similarly, one or two of the "daytime" telescopes are also used at night for high resolution observations of bright stars and solar system objects. Demand for most of the night-time facilities is so great that only a fraction of the those ranked high in merit, during peer evaluation, can be allocated time.

Although facilities under construction or planning elsewhere may eventually eclipse them, the NOAO solar observing facilities are among--if not the--very best in the world. These include the Vacuum Tower telescope on Sacramento Peak (which is acknowledged to be the best operating facility in the world for high spatial resolution observations of the sun) and the McMath Telescope on Kitt Peak (which is the largest solar telescope in existence and almost unique in its infra-red capabilities).

The staff of NOAO numbers at present about 450, of which approximately 12 percent are members of the scientific staff. In addition to assisting visiting observers, NOAO staff scientists carry out research in their own right using NOAO facilities and provide much of the intellectual leadership for improving and extending instrumental capabilities for optical astronomy, both at NOAO and for wider ultimate usage. I shall say more about how NOAO cooperates with university scientists on such developments later. Approximately 20 percent of the observing time on NOAO facilities is currently used by the NOAO staff astronomers, who compete for it on the same basis as all other users.

Mr. Chairman, I wish that time permitted my discussing the very exciting research that is produced by visiting astronomers and staff scientists using these facilities. I do not believe that there has been a time in the history of this science when the pace and quality of discovery was greater than now. But this hearing is concerned with the FY1987 NSF Budget, and before discussing the topics you suggested, I would like to provide some NOAO budgetary perspective.

Distribution of FY1986 NOAO Budget by Category

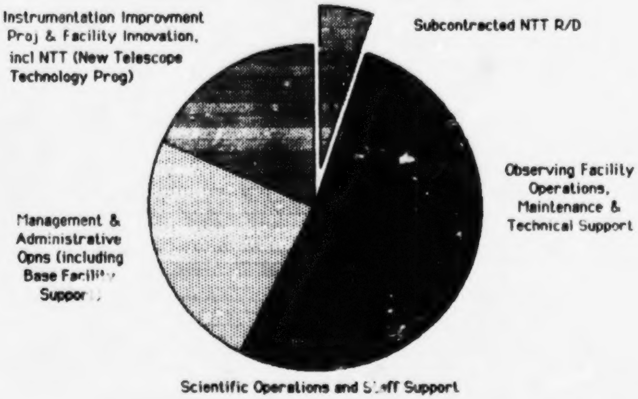

Chart 1

Functional categories of expenses and their share of the NOAO budget for the current fiscal year are summarized in Chart 1. You will note that the largest budget share is devoted to Operations and Maintenance of existing observing facilities at the three sites. A comparable share (at the upper left of the chart) is allocated to Projects for improving instrumentation of existing facilities and for developing innovative technology to make possible radically improved facilities. A key project of the latter type, carried out under the Advanced Development Programs division of NOAO, is the New Telescope Technology (or "NTT") program. You will note from the displaced "slice of the pie" that a substantial portion of that program's budget is "external," subcontracted effort at cooperating universities (principally to the University of Arizona at this time) under overall program management by NOAO.

The smallest programmatic category is the Scientific Operations slice at the bottom of the chart. This includes all personnel and supporting costs for the NOAO scientific staff, including personal research time (approximately 50%), instrumention project activities and other observatories service. The latter includes that time devoted to helping visitors, supporting NOAO committees, such as Telescope Time Allocation, etc. Finally, the budget category (on the left center) for Management and Administrative Support Operations includes central computer services, business and program management, and also maintenance and support for the NOAO base facilities at the two urban locations. These costs, which would probably be budgeted indirectly as "overhead" at most universities, amount to approximately 25 percent of the total.

In order to put my discussion of the FY1987 Budget in an appropriate context, Mr. Chairman, I would like to summarize first some NOAO budget trends over the past decade. It is important to consider not only the funds obligated to NOAO year by year, but also the purchasing power of these funds

NOAO Actual Budget Purchasing Power Compared To NOAO New Oblig in Current Year Dollars

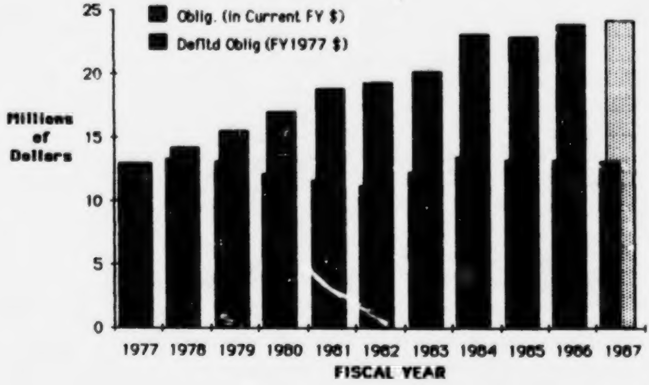

Chart 2

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in constant value dollars. These "deflated" budget levels--i.e., those adjusted for inflation to their purchasing power equivalent in FY1977 $--are compared with NSF funds obligated to NOAO for the past decade in Chart 2. The taller columns on this chart plot current year funds actually obligated or in the "Current Plan" up through FY1986. The FY1987 column is shown lighter, because it is the level requested, and past history has shown that NOAO often experiences a considerable reduction from that value as the budget process matures. The narrow black bars show the purchasing power of these obligations in FY1977 dollars, or what I have called the "deflated" budgets. The adjustments for inflation take into account changes in dollar purchasing power both in the US and in Chile during this period.

The inflation adjustments for NOAO funds expended in the US are based upon the US Consumer Price Index (for Urban Wage Earners) and for those spent in Chile on the comparable Chilean index, converted to dollar values using the monthly average ratios for US dollar to Chilean peso exchange. The Chilean adjustment is important because local economic factors greatly exaggerated the dip in purchasing power of the NOAO budget in the FY1979-FY1982 period, when the exchange ratio was frozen. On the other hand, such conditions have enhanced the budgetary purchasing power for the past three fiscal years.

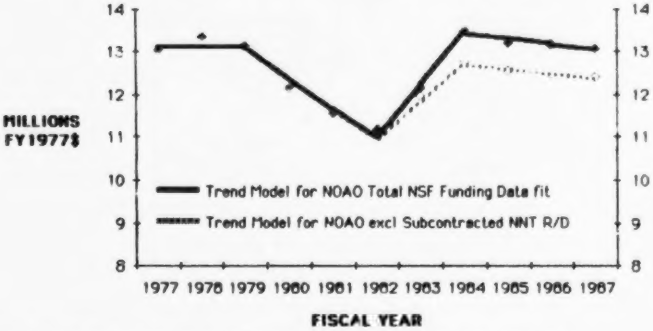
Note that although the trend in yearly NOAO budget obligations has generally been upward, a distinct change in slope occurred in FY1981-FY1983, which was followed by a significant increase in FY1984. Since then, the trend in yearly obligations is generally upward at about the rate experienced during FY1981- FY1983, although current year obligations in FY1985 dropped slightly below FY1984's.

The inflation-adjusted, or "Deflated" obligations show qualitatively different trends from those shown for "Current Year" budgets. As the black columns in Chart 2 indicate, NOAO's budgetary purchasing power was roughly constant from FY1977-FY1979, followed by a decline at a nearly constant rate (5.6% per year) from FY1979-FY1982. It then rose steadily from FY1982 to FY1984, up to a level approximately equal to that experienced during the "plateau" in the late 1970's. It has remained approximately constant at that level for the past three years. As this chart also indicates, the FY1987 NSF budget before the Congress, if authorized, would maintain these funding trends.

However, two additional analyses, displayed in Charts 3 and 4, show why recent years' NOAO budgets have been relatively more inhibiting to maximal use of its facilities than these trends would seem to indicate. First, I must note that the NOAO funding levels in Chart 2 include total NSF funds in the NOAO budget, those in the "subcontracted-effort" slice of the pie in Chart 1 as well as in the "in-house". If these subcontracted efforts were excluded, however, the resultant in-house NOAO obligations and purchasing power show a somewhat different trend.

These are illustrated in Chart 3. In this chart the deflated budgets are plotted as diamonds--black for total-NSF-funds allocated to NOAO, and white for the in-house funds only. The zero budget level is displaced below the axis so that level differences are more clearly evaluated. The downward slopes of the post-FY1984 budget trends are approximately the same for both categories, about 1% per year, but the current purchasing power of in-house NOAO funds is about 5 percent below the purchasing power of the late 1970's while that of the total-NSF-funds is roughly equal. The lines linking the two sets of budget data are best fits to a linear model of budget trends.

NOAO Deflated (Infl Adjust) Budgets for FY77-85 Actuals, FY86 "Current Plan" and FY87 Requested Levels



Deflated by US-CPI (Urban Wage) and Chilean-IPC adjusted for $/Peso Exchange Ratio

Chart 3

NOAO STAFFING TRENDS compared with NOAO DEFLATED BUDGET (FY1977$ in M) [NSF "In-House" Funds only]

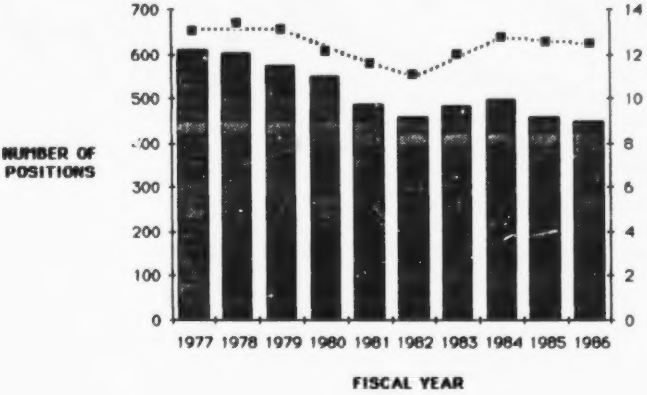


Chart 4

When the in-house NOAO budgets are compared, year by year, with the personnel levels of NOAO in Chart 4, two conclusions emerge:

a. the impact of inflation on NOAO operations, the costs for which are approximately 65-70% personnel-related, is not adaquately estimated using consumer cost/price indices. Although the "constant dollar" budget level of the in-house budget is down only 5%, reductions in the number of personnel by 25% have been necessary over this time.

b. Since AURA wage and salary scales have not increased significantly more than the consumer indices, an additional "deflation" or loss of purchasing power of about 20% over the past decade has been experienced due to the increasing technological complexity of the astronomical research facilities.

Thus, what at first sight appeared to be a reasonably constant level of support for NOAO, ignoring the dip around 1982 for the moment, is seen to be a significantly constraining financial situation.

Potential Impact of Gramm-Rudman-Hollings Sequestration

These NOAO budget trends have not taken into account the potential impact of the Gramm-Rudman-Hollings Act sequestration. An attempt to estimate this is shown in Chart 5, which is comparable to Chart 3.

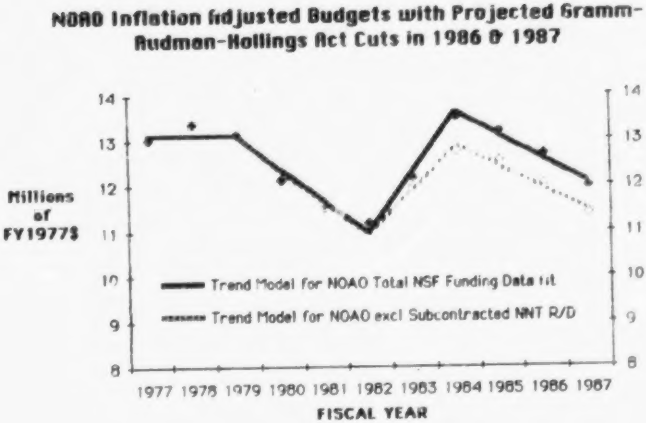
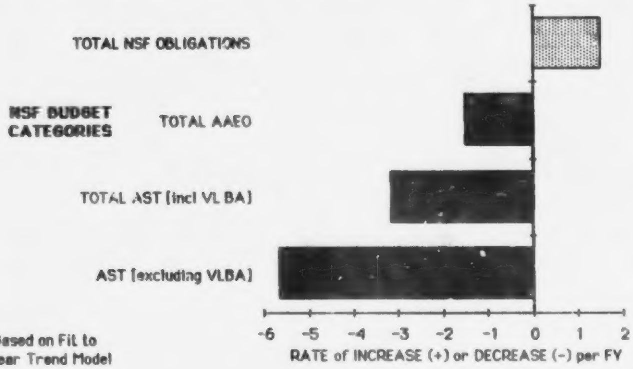

NOAO Inflation Adjusted Budgets with Projected Gramm-Rudman-Hollings Act Cuts in 1986 & 1987

Chart 5

In preparing Chart 5, we have reduced FY1986 Obligations (from the "Current Plan" levels in the NSF Budget) by 4.3% and used a value of 8.4% for the FY1987 reduction, should the sequestration be triggered. The latter was quoted in the Wall Street Journal on February 18th as representing the Congressional Budget Office's current estimate. It has also been necessary to make inflation assumptions between FY1986 and FY1987. We have estimated 3 percent for the US inflation rate, comparable to that used in the historical analysis, and a net 5 percent loss in dollar purchasing power in Chile, reflecting current trends of weakening of the dollar there. Both of these assumptions are probably conservative.

As would be expected, the budget trend lines since FY1984 in this case are more alarming, with purchasing power declining approximating -3.9% per year. Note also that the level of in-house NOAO budget is almost as low as it was at the FY1982 minimum. Similar trends for other NSF budget categories are even more disturbing. These are plotted in Chart 6.

The contrast in these trends is obvious. The greatest impact is on the astronomy budget when VLBA construction is excluded. Of course, all of these negative trends would be increased, should the FY 1987 NSF budget be reduced below the requested FY1987 levels before the Gramm-Rudman-Hollings salami slicer is turned on!


FY1984-FY1987 TREND* of Deflated Budgets Assuming Gramm-Rudman-Hollings Act Sequestration in FY1986-87

* Based on Fit to Linear Trend Model

Chart 6

Impacts on Facility Utilization

Recognizing the national need for budgetary constraint, I urge you to authorize the President's NSF budget and to encourage your colleagues to appropriate funds at the recommended budgetary level. Nevertheless, Mr. Chairman, I have some concerns about "the adequacy of these resources to support maximum utilization of these facilities" which was a question you raised in your letter of invitation to me to testify on this panel.

We have not had enough time to analyze the programmatic impact on NOAO of the recommended FY1987 budget, either with or withour Sequestration, in sufficient detail to discuss them here. However, it is clear that we must consider all possible options to minimize the impact of the increasingly difficult job to carry out NOAO's roles in the overall NSF program, while attempting to run a viable observatory program at reduced purchasing power.

What is certain is that utilization of the NOAO facilities will not be maximal. In FY1986 NOAO has had to change the scheduling patterns on telescopes to minimize instrumental changes. All but the largest telescopes will be shut down for one month next summer at Kitt Peak, during the normal rainy period, to optimize preventive maintenance with a reduced staff and to concentrate vacation periods so that the number of personnel needed during operations to substitute for those on vacation is reduced. Generally speaking, the new scheduling approach will result in fewer users of the facilities, although the scientific impact of this will be off-set to some degree by longer runs, on average. Three nighttime telescopes have been taken out of service, and we hope that the present set will not have to be further reduced.

The solar observing facilities at both Sacramento Peak and Kitt Peak are operating with reduced staff, effectively, but far from maximally. Following the concern raised by uncertainty regarding the continued operation of facilities on Sacramento Peak last spring, AURA and the NSF jointly convened a study group to look at scientific priorities among the facilities and programs of the National Solar Observatory (a division of NOAO). Briefly, the advice of the working group chaired by Dr. Eugene Parker of the University of Chicago placed the Vacuum Tower Telescope, located on Sacramento Peak, highest in priority because of its capabilities for high spatial resolution solar observations, the McMath Solar Telescope complex, located on Kitt Peak second, because of its capabilities for infra-red observations of the sun and for making high spectral resolution observations of solar type stars. Third priority was accorded the rest of the solar facilities at the two sites.

All but one of the major recommendations of the Parker Group were accepted by AURA and by the NOAO and NSO Directors, the NSF has also expressed its concurrence with our response. AURA responded in detail to the report of this group including, in response to their recommendation for a public statement of intent, the following:

> " AURA regards solar physics as a vital part of astrophysics as well as of solar-terrestrial physics. Ground-based observations of the sun are a key part of the national program in solar physics. AURA agrees that the observational facilities and programs at Saacramento Peak and at NSO/Tucson are the cornerstone of the nation's capabilities in this field. AURA is committed to work toward the healthy operation of these facilities, both in FY 1986 and in future years."

AURA is very grateful for the strong support that the US Air Force has given to the operations of facilities on Sacramento Peak. As the NSF Budget detail notes, the Air Force has increased their level of financial support of AURA operations there from $435,000 in FY1985 to $600,000 in FY1986, through inter-agency funds transfer to the NSF. The Air Force staff on the Peak are a vital element of the observatory's scientific environment, and the NSO Director is committed to involve them fully in program planning in the future.

In closing this discussion of facility utilization I would like to present my final chart. It displays the number of visiting astronomers, in addition to the NOAO staff scientists, who have used the NOAO facilities in recent years. Chart 7 shows that up to 1000 visiting observers per year have made use to NOAO facilities. The generally increasing numbers reflect the improved efficiency of observations brought about by instrumental improvements over the years, among other things. Note however the drop in two years. These may just be statistical fluctuations, but it is interesting to note that they correlate in timing to particularly tight budget periods. The fall-off in the most recent year probably reflects the scheduling changes brought about by personnel reductions mentioned earlier, as they began in FY1985. I predict that this reduction will continue, or accelerate, unless additional resources can be found.

Number of Users of NOAO Facilities - 1977-85

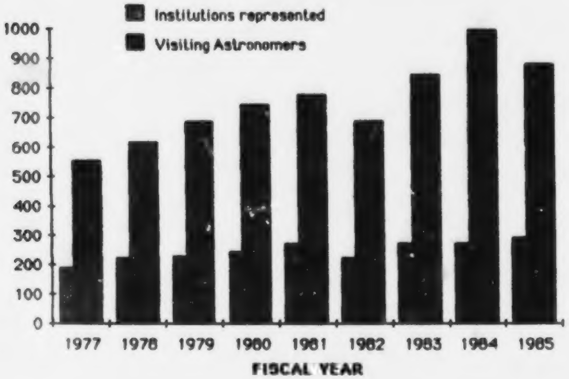


Chart 7

Improvement in Capabilities for Research

Regarding the "adequacy of resources....to improve NOAO's capabilities for research," Mr. Chairman, as I noted earlier such efforts are encompassed in the NOAO "Project" category, which I mentioned in connection with my earlier discussion of Chart 1. In total this accounts for about 25% of NOAO's current budget, including the approximate 5% of subcontracted NTT R/D. This level indicates the high priority that AURA and NOAO management accord improvements of research capabilities.

However, we are squeezed here also. The costs of new instruments for the existing telescopes are increasing due to the technological complexity to which I referred earlier. In terms of personnel resources for such improvements these are down significantly from 10 or even 5 years ago. However, unless the current facilities are upgraded frequently, the National Observatory will soon become obsolete. While many proposed projects have to be rejected, we are maintaining an excellent set of instrumentation.

The program of facility improvement for the SP Vacuum Tower Telescope continues and we hope this facility's capabilities will be strengthened through even greater use by the community who expressed such strong support for it. AURA is also gratified that the NSF and its peer review panels have given strong encouragement to NOAO to establish a network of automated solar observing stations around the world to study with higher resolution the so- called "global oscillations" of the sun.

Other Issues

Mr. Chairman, you also invited me to comment on any other issues that I wished to bring to your attention. I have selected two. The first is the nature of the New Telescope Technology Program and the second is the issue of whether management of governmental research by university consortia has any benefits.

NTT Program Discussion

When this program began about six years ago, AURA was able to bring together scientific representatives of three major universities, each of which had interests in advancing telescope technology and aspirations to build large telescopes for use by their colleagues. The NSF had been supporting conceptual design studies for a "new generation telescope" at NOAO's Kitt Peak National Observatory and each of the Universities of California, Arizona and Texas had technical and design efforts under way supported by state funds. The goal of this collaboration was to coordinate "new telescope" technology developments and thus use the limited state and federal funds available most efficiently, by avoiding duplication of effort, sharing research results and jointly determining which tasks were of the highest priority.

A multi-option R/D strategy was agreed upon, following three variations of technical approach which had been identified as most promising in the earlier Kitt Peak studies. These revolved around the use of

i) segmented mirror technology,
ii) thin monolithic mirrors with dynamic supports, and

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iii) multiple mirrors utilizing proposed new techniques of casting large borosilicate blanks.

Technology development for technology's sake has often proven sterile, so it was agreed that telescope concepts in three size ranges were to be identified to focus the techical efforts. These revolved around telescopes of three equivalent diameters, 7 meters, 10 meters and 15 meters. The various approachs shared some problems in common, but each had some unique challenges. Although there were some restrictions on where the various state funds could be spent, tasks which were identified through a coordinating committee as being of highest priority within the total of state and federal funds available each year, were generally assigned where it was agreed that the best talent lay. Thus, it turned out that NOAO efforts contributed significantly to the segmented mirror technology, which has been chosen by the California Association of Universities for Research in Astronomy (the University of California and the California Institute of Technology) as the technical approach for the 10 meter Keck telescope.

The improvements in performance/cost that the NTT program has as goals are so great that individual universities or institutions may reasonably aspire to future telescopes of 7 meter size, a large university, or collaboration such as the California one, may aspire to one of 10 meters, but it was agreed by the NTT coordinating group that a 15 meter telescope only made sense as a national facility. For this reason, the concept of a 15 meter equivalent diameter "National New Technology Telescope" has been one template for guiding and evaluating new optical/infra-red telescope technical developments. A group of distinguished astronomers, none of whom were involved in any of the technology development efforts, was assembled about three years ago as a "scientific advisory group on the NNTT." This group was asked to recommend--on the basis of their evaluation of the scientific objectives for a telescope of this size range--which approach would be best for such a potential facility. After about 18 months of deliberation, this peer group recommended to AURA that a four-barrel, multiple mirror approach, based on the large mirror casting technology under development at the University of Arizona--under the creative leadership of Prof. Roger Angel--has the highest promise for this size range and is the best concept for guiding the NTT program at this stage.

However, the mirror technology upon which much of the NTT effort is now being focused has potential applicability for potential new optical observing facilities in the range of sizes from 3 meters up, so this effort under NOAO management benefits astronomy broadly. Specifically, a "mini-consortium" of universities (Chicago, Washington, Princeton and the University of New Mexico at Las Cruces) proposes to build for their restricted access a 3.5 meter advanced technology telescope on Sacramento Peak using an early stage mirror blank developed within this program. The Japanese have approved the construction of a 7.5 meter telescope using such a mirror which will be located at the Mauna Kea Observatory of the University of Hawaii. Additionally, the Carnegie Institution of Washington plans at some future date to construct and install an 8 meter telescope at its Las Campanas Observatory in Chile, perhaps with the collaboration of one or more universities. Several other New Technology Telescopes of this size or larger are in the fund raising or discussion stages. Thus, even though the impact of the sizable "extramural" portions of the NTT program on on-going facility support is sizable, AURA is committed to carrying such efforts forward as long as funding levels allow.

I wish to emphasize that the NSF has not approved any project with the objective of constructing a national facility based on this concept, nor is it proposing such in the FY1987 budget request. AURA fully supports the priority for the VLBA construction and I would like now to urge the Congress to fund this authorized program at as high a level as possible in FY1987, because it will be of great scientific benefit to this nation. But we also believe strongly that, to remain viable, a national observatory should be committed to innovation and to providing future facilities for its astronomical constituency, many of whom do not or will not have access to private or state owned optical observatories, with equivalent or greater capabilities. Thus, AURA has a high priority goal to propose, when the technology is clearly proven and the funding environment is more propitious, the establishment and approval of a program for constructing an NNTT.

The NSF has set up an ad hoc study group under the Advisory Committee for Astronomical Sciences (ACAST) to consider national needs for large aperture telescopes in the context of the prospective completion of the Keck Telescope and possible other private or state facilities. AURA awaits the report of this group with considerable interest; it should be available after the next ACAST meeting in April.

Management by University Consortia

It is appropriate to ask whether management of the NSF's major research centers by university consortia brings any special benefits. Management entities such as AURA and the other university related organizations represented here differ substantially from traditional government or industrial laboratory entities, and even from individual universities. The issue might be raised whether these are appropriate vehicles for managing such important activities as national research centers. I would like to suggest some benefits from utilizing such management arrangements:

1. Program trade-offs proposed under constrained budgets are reviewed and approved by representatives of the astronomical communities directly affected by the results.

   In AURA's case this is done by the astronomers who make up about two-thirds of the Board's membership, with the help of the university financial and academic administrative officers who also serve on its board.

2. Management costs are minimized.

   For example, the annual cost of the corporate operations of AURA which are related to its management responsibilities for NOAO -- including its paid staff, and the travel costs of the AURA Board and its committees -- is less than 1.8% of the NOAO budget.

3. These member universities and directors have a "built-in" motivation to achieve the most research for the least overhead costs.

   Specifically, maximal resources are devoted to facility operations and their improvement for research use. Operations and costs of corporate management are tightly constrained by the Board.

4. Member universities contribute substantial human resources toward management oversight functions through service of their scientists and administrative officers (who contribute on a non-paid basis) on Consortia Boards and Visiting Committees.

   This is one reason for low management costs. A recent estimate of the dollar value of such contributed time borne by the consortium members and other universities, in AURA's case, was as much as half AURA's management fee provided by the NSF.

5. University relationships of the managing consortia facilitate recruitment and retention of high quality scientific management and staff for the national centers.

   Such relationships also facilitate cooperative efforts in instrumentation and facility technology developments.

This concludes my testimony. I am prepared to answer any questions.

QUESTIONS FOR
Dr. John M. Teem, President
Association of Universities for Research in Astronomy, Inc.

1. **Please provide for the record a brief summary of:**

   a. **the percent of AURA's total budget provided by NSF;**

Answer The total AURA budget in FY 1986, including currently planned budgets for AURA managed NOAO and ST ScI derived from budget allocations under the prime contracts for these two Centers (before any reductions under the sequestration of funds under the Gramm-Rudman-Hollings Deficit Reduction Act) is $42,640,000. This is broken down as follows:

Source of Funds	Dollars in Millions	Percentage
Total AURA	42.64	100%
NSF - NOAO	23.64	55%
NASA - ST ScI	19.00	45%

The FY 1986 budget for AURA Corporate operations, as currently planned, is $743,500. The AURA contract with NSF provides for a FY 1986 Fee of $417,000. However, the Gramm/Rudman/Hollings Act will reduce this to approximately $397,000 in FY 1986. The percentage amounts will then be as follows:

Source of Funds	Dollars in Thousands	Percentage
Total	743.5	100%
NSF Fee	397.0	53%
NASA Fee	221.0	30%
AURA Capital Reserve & Other Income	125.5	17%

   b. **the portion of AURA's management or consultant fee received from NSF, compared to funds for research, and for facility maintenance and up-grade;**

Answer Management fees received from the NSF represent 1.8% of total direct costs. The currently approved FY 1986 Program Plan for NOAO is $23,640,000. This total is divided as follows:

Total	$23,640,000	100%
Operations & Maintenance	14,116,000	59.7%
Advanced Development	3,072,000	13.0%
Other Scientific Projects & Staff	6,035,000	25.5%
AURA Management Fee	417,000	1.8%

The FY 1986 Plan will be reduced by just over $1 million as a result of the Gramm-Rudman-Hollings Act. However, this adjustment should not affect the Management Fee percentage since Fee will also be reduced.

c. the portion of AURA's funds allocated for overhead and what that overhead includes;

Answer All of the costs incurred for the operation of AURA, Inc. are funded by the Management Fee, or when that is inadequate, as in FY 1986 for example, by drawing upon the AURA Capital Reserve account. AURA does not receive funds separately for overhead costs, either for Corporate operations or at AURA managed Centers. AURA does, however, incur traditional overhead costs such as office rental, supplies and services, audit and legal services, Board and Committee meeting expenses, travel, etc.

All costs under AURA's prime contracts are charged directly. NOAO does have established overhead rates, approved by the NSF, which are applied to modified total direct costs (MTDC) or other applicable measures of work done at NOAO for other agencies through interagency transfer of funds to the NSF. These rates vary with the type and location of such work; the rates in effect for this fiscal year are tabulated below.

General Rates	Rate	Applied to:
General & Administrative (Off-Site)	17.4%	MTDC*
On-Site - Tucson, AZ	21.8%	MTDC
On-Site - Kitt Peak, AZ	45.4%	MTDC
On-Site - La Serena, Chile	29.8%	MTDC
On-Site - Sunspot, NM	42.9%	MTDC
Engineering Burden	71.3%	Engineering Direct Labor
Observing Burden - Arizona	80.1%	Observer Direct Labor
Kitt Peak Mountain Burden	55.0%	Mountain Staff Direct Labor

Special Purpose Rates	Rate	Applied to:
Personnel & Accounting Services Only	2.3%	MTDC
Kitt Peak - Joint Use	$ 0.64	Mountain Building Sq. Ft.
Facilities Use:		
Tucson	$16.13	Building Sq. Ft.
Kitt Peak	$19.60	Building Sq. Ft.
La Serena	$14.67	Building Sq. Ft.
Sunspot	$12.67	Building Sq. Ft.

* MTDC = Direct cost other than equipment purchases, subcontract expenditures exceeding $25,000 per subcontract per year and management fee.

Because of the complexity of this schedule, it is difficult to estimate an average "overhead" rate, but the most commonly applied indirect cost burden is the On-Site - Tucson rate, and an average overhead rate for all programs is probably about 25%.

d. the membership fee AURA charges to participating universities and how the fee is utilized by the consortium;

Answer The originally established membership fee was $2,500. All current AURA member universities have paid that fee. In 1981, however, the membership fee for any additional members was raised to $10,000 each. No new member universities have been accepted since that date. All fees become part of AURA's Capital Reserve fund.

e. how are the AURA facilities managed to assure the equipment, instrumentation and bricks and mortar are maintained and properly renovated? Do the centers include a separate line item for this end of operations?

Answer AURA's central mission is to maintain and operate optical astronomical observing facilities and the assurance of up-to-date equipment and instrumentation is an important aspect of this central mission. The AURA managed centers do not include a separate budget line item for maintenance of buildings (bricks and mortar) or current instrumentation, but the costs for such efforts are included under the "Operations and Maintenance" budget line. In addition, NOAO has a separate organization and budget for Central Facilities Operations. The development of new instrumentation is covered under the budget line for "Scientific Projects." Budget pressures have reduced our investment in the development of new instrumentation to an uncomfortably low level, but we have managed to maintain existing equipment and instruments at a reasonably high level.

f. functions or characteristics of AURA which are uniquely different from the other NSF large-scale facility management consortia.

Answer The most obvious unique functions of AURA relative to other NSF facility management consortia, relate to our disciplinary focus on optical/infra-red astronomy. The facilities of NOAO represent the largest collection of astronomical facilities in the world for research at these wave-lengths. Scientists from all over the world use these facilities for research in solar, planetary, stellar, galactic and extragalactic studies. Approximately 80% of the users of these facilities are visiting astronomers or graduate students who are not members of the NOAO staff.

There are obviously many common characteristics among these organizations. The other consortia can make similar disciplinary statements for radio astronomy, the atmospheric sciences, and ocean or earth sciences. Also, there are many similarities in operational style, such as the utilization of discipline-oriented peer review committees for advising Center Directors on allocation of access to facilities use, and the use of oversight committees of scientists within these disciplines for reviewing the performance of the centers. All the consortia utilize Boards of scientists and university administrators, as well, in the management oversight of their large-scale facilities.

One characteristic of AURA's management which I believe differs somewhat in style, although not so much in function, from that of at least some of the other NSF center managing organizations, is the depth to which its Board is involved as a disciplinary peer group in advising the Center Director on scientific priorities and long range scientific goals of the Observatories, as well as in reviewing the plans of the Center prior to their submission to the NSF. (See my answer to question 4, also.)

2. How much overlap is there among the university members of the various consortia? Is a separate consortium required for each discipline, and why? Could management economics be realized using one university consortium as the management organization for all NSF large-scale facilities?

Answer There is some overlap among the University members of AURA, AUI, UCAR, and JOI. For example, essentially all the AURA members are also members of UCAR, just over half of the AUI associated universities are members of AURA, and about a third of the JOI members are also members of AURA. It should be noted that this overlap occurs because of discipline-oriented departmental strengths within these universities, which include most of the major research universities of this nation. There are several hypothetical organizational possibilities for management of the NSF large-scale facilities and there are arguments both for and against these various possibilities. I believe that the involvement of scientists knowledgeable with the discipline is essential in the operation of at least the astronomical facilities. Some of the arguments for discipline-oriented facility management organizations are:

a. Program trade-offs proposed under constrained budgets are reviewed and approved by representatives of the astronomical community directly affected by the results, i.e., peer groups. In AURA's case, this is done by the astronomers who make up about two-thirds of the Board's membership, with the help of the university financial and academic administrative officers who also serve on its board.

b. These discipline representatives and directors have a "built-in" motivation to achieve the most research for the least overhead costs.

Specifically, maximal resources are devoted to facility operations and their improvement for research use. Operations and costs of corporate management are tightly constrained by the Board.

c. Member universities contribute substantial human resources toward management oversight functions through service of their scientists and administrative officers (who contribute on a non-paid basis) on consortia boards and visiting committees.

This contributes to lower management costs. A recent estimate of the dollar value of such contributed time borne by the consortium members and other universities, in AURA's case, was as much as half AURA's management fee provided by the NSF.

d. Discipline representatives on the managing consortia facilitate recruitment and retention of high-quality scientific management and staff for the national centers. Such relationships also facilitate cooperative efforts in instrumentation and facility technology developments.

The question of whether a single consortium used for managing all the large-scale facilities of the NSF would lead to management economies is one that I have not studied in depth, but I will give you a personal opinion based on my experience in managing industrial, government and university research efforts. I do not believe that consolidating management for multiple disciplinary-oriented research centers would be as effective as the present, single disciplinary management organizations provide.

I recognize that in AUI there is a model for an organization that does an effective job of managing a multi-disciplinary research center, the DOE's Brookhaven National Laboratory, as well as the single disciplinary National Radio Astronomy Observatory of the NSF. However, in regard to research operations, it is my experience that the best management comes from a focussed, single purpose or single discipline organization. Among the DOE Laboratories I would cite as most successful the Fermilab, managed by the Universities Research Association, or the SLAC.

For astronomy, in particular, I believe that the various disciplinary groups involved with optical or infra-red observations feel very strongly that they should have as much influence as possible on the management policies of their observational facilities. As an example, some solar astronomers are strongly recommending that the NSF's solar observational facilities be reorganized under a management organization that would focus only on the discipline of solar physics, because they do not trust the night-time astronomers to give appropriate priority to solar physics when budget pressures become tight. I do not know how any of the disciplinary subcommunities in astronomy would feel about atmospheric or ocean scientists reviewing their work, but I suspect that similar distrust would be evident.

While there would be some economies in a single management organization--for example--there would be only one president's salary--I suspect that the organization would need to develop a considerable staff to deal effectively with the policy and management issues that arise, which would decrease the savings from that source. Since I am retiring in September, 1986, I do not see this possibility as any "threat" to my own job security, however, and believe that my opinion is objectively based. However, as I noted, there are advantages and disadvantages to any organizational approach.

3. NSF's major national research centers provide the entire university research community with access to large, and often unique, research facilities. Operation of the major research centers in astronomy, atmospheric research, earth sciences and ocean sciences comprise about 10% of the NSF research budget.

Do you foresee growth in the national research centers in order to provide greater access and improved capabilities?

Answer Unless the facilities of the national research centers are upgraded in pace with the needs of their fields, over time their value will decrease below that which is cost-effective. At present, the VLBA, which is of highest priority for astronomy, is authorized and under construction; its completion will provide needed improvement for national radio astronomy facilities, and when combined with the VLA and NAIC dish provide US astronomers with world-class observing facilities at radio wave lengths.

The capabilities of the National Optical Astronomy Observatories have been improved during the past decade through significant advances in the sensitivity of detectors for visible wavelengths and increases in the data handling capabilites of the instruments in which those detectors are placed, realized through significant improvements in computer hardware and software for analyzing the photons collected. However, improvements in quantum efficiency of visible detectors have essentially reached theoretical limits. Larger sized detectors are under development, and research and development is under way at NOAO on improved optics and mirror coatings to increase the photon collecting efficiency by a small amount, but the capabilities of existing telescopes will not be improved much more, except in the infra-red, where advanced detector arrays are being tested this year.

Even with these improvements in optical capabilities, NOAO facilities have not been able to meet the demand. The number of observing proposals ranked superior to outstanding in peer reviews, on the basis of their scientific merit, for the larger NOAO telescopes (e.g., the 4-m telescopes on Kitt Peak and Cerro Tololo) is three to four times the number that can be accommodated in an observing cycle. Even for the 0.9-m telescopes which, when equipped with the current instrumentation, can carry out research that could be done only with the 4-m Mayall Telescope on Kitt Peak or the 5-m Palomar Telescope of Caltech 10 to 15 years ago, are oversubscribed by factors of three for superior to outstanding scientific proposals.

One factor in this demand has been the need to make correlative measurements at visible wave lengths on the ground for objects observed with radio telescopes or for objects observed from space at ultraviolet and X-ray wavelengths. It is through such measurements obtained with ground-based optical facilities that much of the understanding of astronomical objects, often discovered at other wavelengths, has been obtained over the past 10-20 years. This interdependence of space- and ground-based astronomical observations is well understood within the astronomical community, but sometimes not so well appreciated by non-astronomers.

For the reasons discussed above, if astronomy is to fulfill the promise that NASA's space observatories (such as the Hubble Space Telescope and the Gamma-Ray Observatory) and the new radio facilities offer, the optical and infra-red facilities of NOAO are going to need to be improved through the provision of greater photon collecting capability, i.e., larger sized telescopes.

The 10-m Keck Telescope of the California Association of Universities for Research in Astronomy--which has no connection with AURA in spite of its similar name and the fact that its member universities are members of AURA--is being made possible through private donations by the Keck Foundation and the support of the state of California. Consequently, no significant fraction of time for observing with it will be available to astronomers other than those on the faculties of the two named universities and the University of Hawaii, on whose Mauna Kea site the Keck telescope will be located. These number between 10 and 15 percent of the astronomers currently making ground-based optical astronomy observations. While this marvelous facility, which will carry on the tradition of private and state support for ground-based optical observatories, will be extremely important for advancing astronomical sciences, many important advances in astronomy are currently being made by astronomers from other universities.

The primary rationale for the existence of National Observatories is that access to such facilities is based solely on the potential scientific merit of the use proposed, so that they are accessible to all US astronomers on the same basis, regardless of their institutional relationship. Unless observing facilities comparable in capabilities to those of major private observatories can be provided, there will be a significant impact on the national astronomical program over the long term. As I noted in my prepared testimony, the goal to which AURA aspires for providing the needed additional capability at NOAO is the NNTT--a four barrel multiple mirror telescope for observations at visible and infra-red wave lengths--which would have an equivalent diameter of 15-m and would be based on the technological developments of the NTT program. This goal is consistent with the recommendations of the NAS's report of its Astronomy Survey Committee, chaired by George Field, entitled "Astronomy and Astrophysics for the 1980's," which placed "a new technology telescope of the 15-meter class" third in priority among its recommendations for Major New Programs.

Although operation of all the major research centers represents about 10% of the NSF's budget, the NSF astronomy centers in total represent only 3.7% of the NSF total. I do believe, however, that new facilities for optical/infrared astronomy will need to be authorized in the next decade if NOAO is to remain a viable center for use by the astronomy community. No new optical telescope has been authorized for the national observatories for twenty years. Although the technological advances which I summarized above have enabled the NOAO to provide observing facilities over the past decade that have been used for a larger fraction of scientific papers based on measurements in this wave length than any other observatory in the world, it will not be able to meet community needs unless some larger facility is authorized.

Assuming that funding for major new optical facilities were delayed until after the VLBA is completed, because of the national need to constrain growth in the federal deficit, I believe that an NNTT could be constructed within a total budget for NSF astronomy centers approximately ten percent larger than the present. Thus the incremental cost for this would be roughly one third of one percent (1/3%) of the NSF's budget. Thus, I do not foresee "substantial growth" in the funding required for the national research centers through the next decade.

4. What is the role of the consortium, versus the director of the national facility managed by the consortium, in setting research priorities, budget levels, personnel ceilings and salaries for the national facility?

Answer The Director of NOAO has overall responsibility for the conduct of the program of the Observatories in a manner consistent with the policy guidelines provided by AURA and the NSF and, as appropriate, for recommending extension or modification of such policy. This program is conducted in accord with specific annual Program Plans, which are approved first by the AURA Board (through its committee structure) and then by the NSF, before the program is carried out. Among the Director's specific functions there are several which relate to the determination of resource priorities, budget levels, personnel levels, and salaries. These include:

1. preparing and submitting to the NSF, subsequent to AURA approval, both annual and long-range (5 year) program plans which reflect the needs of the astronomical community, including NOAO's scientific staff; such plans identify the levels of personnel required consistent with budget level and program content.

ii. maintaining contact with the scientific community in order to remain informed on community needs which should be represented in NOAO's plans and to obtain an evaluation of activities proposed and under way in NOAO.

iii. establishing and administrating procedures for allocating resources within NOAO, both as an input to planning and, after plans are approved, in implementing them.

iv. within AURA's salary ranges for scientific and non-scientific positions established by AURA's president with the approval of the NSF, and within annual salary adjustment pools established by AURA's Executive Committee of the Board, setting salaries for NOAO personnel on the basis of merit determined through annual reviews of performance; individual salaries above a certain level require prior concurrence of the Executive Committee and the Director's salary is set by AURA at a level approved by the NSF.

AURA delegates considerable authority to the Director for conducting the NOAO program and for serving as the principal interface for NOAO programmatic matters with the NSF, as well as serving as the interface with the NSF on many contractual matters. However, as is clear from the above, AURA's Board of Directors--including representatives of the astronomical community and experienced university administrators--are involved in all major decisions in these areas, as is the NSF. For example, in preparing the annual Program Plan required by NSF the Director of NOAO carefully considers the programmatic options that are consistent with annual budget guidelines provided by the NSF and discusses these with the Observatories Advisory Committee of the Board (OAC). The members of this committee devote considerable effort each year toward becoming familar with NOAO programs and operations. Many of the OAC members are also users of NOAO facilities. Suggestions regarding scientific priorities are not infrequently offered by this committee.

After considering these and the various inputs from the community that he gets through the Users Committees for each scientific program and other advisory groups available to him, the Director prepares a draft plan, either annual or long range, which is reviewed first by the OAC. This Plan addresses priorities among scientific projects, allocation of resources among the scientific programs of NOAO (including personnel ceilings which consistent with the NSF's budget guidelines), as well as the strategies recommended for carrying out the NOAO's mission. The Plan is then submitted to AURA's ten member Executive Committee, which is authorized to act for the Board. After considering the recommendations of the OAC and reviewing the Plan themselves, the Executive Committee approves it prior to its submission to NSF. If major policy issues are identified, the Executive Committee either requests the Director to consider necessary changes or these are taken to the full Board at its annual, or a special, meeting for resolution before the Plan is completed and submitted to the NSF.

I want to emphasize that the NSF has final authority over any major policy issue involving the National Observatories, including explicitly whether a facility is to be continued in operation or how the Observatories are organized. It is AURA's responsibility to recommend any and all actions which it believes are in the best interests of the community and the NOAO in such matters to the NSF, and AURA expects the Director of NOAO to advise it of any significant issues and the options for their resolution, as well as his recommendations regarding the best course of action on such matters. But neither AURA's or the NOAO Director's recommendations are tantamount to a decision, notwithstanding views to the contrary by some members of the solar astronomical community. In point of fact, the NOAO Director did not formally recommend closing Sacramento Peak to AURA, although he considered doing so for what he considered good reasons, nor did AURA recommend such to the NSF.

5. As international participation in your research activities increases, are new problems created, (for example: obtaining permission to conduct research in the "exclusive economic zone"; political issues which could destabilize the support of the program; and intellectual partnership and scientific exchange)?

How do you prepare for sustained international program support, and what is the consortium's role versus NSF's role in this regard? How do you plan to involve additional nations in the cost-sharing of your international science programs?

Answer International participation in NOAO programs has been important for many years. Through NOAO, AURA operates one of the few major US basic research installations in a foreign country, the Cerro Tololo Inter-American Observatory near La Serena, Chile. Cooperative working relationships with the scientific communities, not only of Chile but of all American nations, has made this an outstanding research institution, smoothly operating through times of economic and political turmoil under different governments. International participation extends beyond CTIO, including foreign scientists utilizing all the other NOAO facilities and special arrangements for location of observing instruments, such as the Global Oscillation Network (GONG), at several sites around the world. Foreign Scientists compete with their peers for time on NOAO telescopes and this participation totals about 16% of visitor usage over the past few years. Programs such as GONG must be planned with NSF and our contract provides the following:

> "a. The NSF Act requires that the NSF obtain the approval of the Secretary of State prior to entering into agreements with or making commitments to organizations or individuals in foreign countries or agencies of foreign countries. As a result, the NSF, as Federal funding agency for the NOAO, needs to have advance knowledge of, and participate in the planning and coordination, where appropriate, of all Contractor and NOAO activities supported in whole or in part by funds from this contract involving joint programs with foreign entities.
>
> b. Accordingly, prior to making a commitment to such foreign entities as described above, the Contractor shall submit to the NSF advance notification of proposed plans for international scientific cooperative programs that involve the use of NOAO personnel, facilities and/or services."

Although foreign operations have brought on a number of problems, e.g., rapidly falling purchasing power of the funds allocated by the NSF for CTIO operations during the period when the Chilean government regulated currency exchange in a time of high inflation in that country, the resultant access to the southern hemisphere skys by US astronomers has been worth enduring them.

Chile and other American nations have not shared in the funding of CTIO. AURA purchased the land upon which the observatory and base station are located using corporate funds, so that CTIO is not regarded in Chile as a US installation; this has been helpful during times when US relationships with Chilean governments were strained. But the various Chilean governments have been helpful in many ways, e.g., granting CTIO the status of an international scientific installation (which brings some benefits) and declaring the land around Cerro Tololo a scientific zone, prohibiting mining operations nearby.

As an example of potential cost-sharing with other nations that resulted from the initiative of AURA, the NOAO Director reached informal agreement with a Canadian astronomical organization which had a 4-meter mirror blank available, whereby they would provide it and make a contribution towards its figuring for use in a proposed 4-meter infra-red optimized telescope to be located at CTIO. The Canadians' willingners to make such a contribution, which was worth about $2,000,000, was based on the fact that Canadian astronomers appreciate the opportunity that they have to compete for time on the NOAO telescopes, especially in the southern hemisphere. Because of this they were willing to contribute it without any commitments for special priviledge or telescope access. However, the proposed new telescope was not approved by the NSF, so no such arrangement was actually made and the Canadians have since sold the blank.

6. Does your organization purchase insurance for reimbursement of loss, damage, or penalty (indemnification)? What is the cost of this insurance and what level of protection is provided by insurance you purchase? Who would pay damages not covered by the insurance or if insurance protection levels are exceeded? Do you have recommendations on how indemnification should be addressed by the government?

Answer AURA insurance coverage and estimated annual premiums are as follows:

Coverage	Limits	Estimated Annual Premium
Employee Dishonesty		$ 1,600
- Employee Theft	$ 250,000	
- Depositors Forgery	250,000	
Directors & Officers	5,000,000	4,300
Special Coverage	1,000,000	1,300
Package Policy		
- Automobile Liability	500,000	27,000
- General Liability	500,000	
- Contents	1,000	
Property Policy	359,500	1,800
Umbrella Liability	10,000,000	7,900
Foreign		
- General Liability	500,000 CSL	1,300
- Automobile	500,000 CSL	3,100
- Property	400,000	725
- Fidelity	10,000	1,500
TOTAL		$ 50,525

The AURA contract with the NSF provides for reimbursement of reasonable costs of insurance for liabilities to third parties, including indemnification of Officers and Directors of the Corporation in the good faith exercise of their duties. AURA is liable for judgments not covered by insurance or where insurance protection levels are exceeded. However, the AURA contract with NSF provides that:

> "In the event the Contractor incurs liabilities to third persons in the performance of this contract other than through loss or damage to property or for death or bodily injury not compensated by insurance or otherwise, NSF shall make good faith efforts to provide or obtain relief, including good faith efforts to obtain the obligation of additional funds hereunder. The Director of the Foundation, in his or her sole discretion, shall determine the appropriateness of reimbursement of the Contractors for any loss as provided for in the preceding sentence."

AURA's NASA Contract promises to reimburse AURA for compensation paid to third parties for property or bodily injury in excess of the contractor's insurance. However, this means that the government's promise is not open-ended but is limited at any given time to the amount of funds in the Estimated Cost in the Contract Schedule that have not been expended by that time.

The new "Insurance -- Liabilities to Third Persons" clause in the Federal Acquisition Regulation (FAR), which is mandatory for future contracts, is conceptually more attractive than our current coverage. The clause provides that the government's promise to pay for liabilities in excess of insurance is made "without regard to and as an exception to the limitation of cost clause of the contract." However, the clause remains "legal" in that it also contains a new paragraph that makes the government's promise "subject to the availability of appropriated funds at the time a contingency occurs." This apparently means the unexpended balance in the appropriation of the agency that is funding the contract. In the case both NSF and NASA, this is a large enough amount to cover almost any contingency.

We believe that the government's obligation to cover liabilities not covered by insurance should be clearly stated--perhaps through legislation addressing this problem.

7. What effort do you make to increase the number of universities which are members of your consortium? What is being done to assure that talent in non-member universities is involved in the consortium research planning and priorities?

Answer AURA does not actively seek to increase its membership but it does consider applications for membership in accordance with established critieria. The involvement of talent from non-member universities is assured by appointments of at-large directors on the AURA Board, at least 5 of whom AURA's By-Laws require must not be associated with AURA member universities, by drawing on such individuals for service on User Committees, and by their appointment to the Visiting Committee which annually reviews overall performance of the Observatory.

8. Is your contract with the National Science Foundation clear as to what the consortium manages, how and what the lab or project director manages, and what the responsibilities are of the NSF and National Science Board? Please describe policies and criteria which clarify these responsibilities.

Answer AURA believes that its contractual responsibilities to the NSF are reasonably clear. Article III, Scope of Work, provides:

> "The Contractor shall be responsible for the management, operation and maintenance of the National Optical Astronomy Observatories (NOAO) and for the planning, initiation, and execution of their programs and activities. The Contractor shall ensure that the facilities retain their character as visitor oriented astronomical research centers with strong internal research programs, and will make a substantial fraction of the observing time on the major research instruments available to the rest of the astronomical community. In particular, the Contractor shall: . . ."

This general statement is followed by three pages of specific responsibilities. Article IX, NOAO Officials, states:

> "The NOAO Director is the Contractor official responsible for the management of NOAO. Assignment of additional duties to the Director by the Contractor that might result in reducing his/her effectiveness in managing the Observatory is of concern to the NSF. Accordingly, assignment of additional duties requires NSF approval, if these will require more than 10% of the Director's attention."

In addition, the AURA Policies and Procedures Manual provides a detailed position description for the Director of NOAO and for the President of AURA. Each of these position descriptions addresses the relationships between the President, the NOAO Director, and the AURA Board.

The responsibilities of the NSF are clearly called out in AURA's contract, but the responsibilities of the National Science Board are not mentioned.

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QUESTIONS FOR DR. TEEM
ON THE NATIONAL OPTICAL ASTRONOMY OBSERVATORIES (NOAO)

1. **How is NOAO balancing funding to meet the demand for access to its existing telescopes with the need to develop new technology for the next generation of telescopes?**

If level budgets continue, do you envision the necessity to shut down lower priority telescope facilities in favor of operations at the high priority facilities? Have you begun to plan for this possibility?

Answer Under any budgetary circumstances NOAO believes it can move towards its goal of advancing U.S. astronomy only through maintenance of a program which both supports the contemporary scientific efforts in the U.S. and makes a significant commitment to the future. In a time of decreasing resources this is no less true, although the balance between present and future will certainly depend on funding. Thus we have reassessed the scope of our study and planning efforts for the next generation of telescopes so that while keeping these viable, we place greater relative emphasis on operation of existing facilities.

At level funding we shall be increasingly hard-pressed to maintain all facilities open and available to users. We have already reduced the scope of operations at smaller telescopes by limiting instrument changes and by reducing support to visiting observers. We shall continue to limit services before closing telescopes (although we have closed some 16-inch telescopes which were in little demand). In fact, there is little consensus on priorities beyond the largest telescopes. The smaller telescopes contribute out of proportion to their collecting area as measured, e.g., by productivity of scientific publications, graduate student theses, and prizes awarded on the basis of research conducted at these facilities. This has come about through development of highly sensitive linear detector systems which makes today's 36-inch telescope the equivalent in power to the 200-inch telescope of a past era when photography was the only way of recording astronomical information.

Planning for possible shutdown of facilities has not extended beyond attempts to prioritize among existing telescopes and limit expenditures for instruments and improvements to the higher priority instruments.

2. **In some cases individual universities already operate, or are proposing to build on their own, telescope facilities that are similar to those at, or proposed for, the National Optical Astronomy Observatories System.**

What are the prospects of combining the resources of the national observatories with those of individual universities?

For example, could the new Keck Telescope, a privately financed, Cal Tech - University of California project, be integrated into NOAO, if some mutually beneficial arrangement were found?

Answer We are convinced that U.S. astronomy will be significantly advanced if we are able to combine resources with those of other institutions and have widely advertised our interest in initiating discussions along these lines. We have held detailed discussions with two U.S. institutions interested in constructing telescopes in the northern and southern hemispheres and have begun discussions with a third. We have initiated discussions with a European group in connection with collaboration on a large solar telescope (LEST), and with Canadian interests in respect to a southern hemipshere telescope. We shall continue these discussions aggressively in the belief that this is decidely in the best interests of U.S. astronomy as a whole.

We would certainly consider seriously an arrangement with the Cal Tech/U. of California consortium in regard to the Keck telescope if that would benefit U.S. astronomy as a whole.

3. **We have learned that AURA's optical observatories were reorganized some 2 1/2 years ago to form the National Optical Astronomy Observatories (NOAO), bringing the management of these facilities under one Director with the emphasis at the time being on centralization.**

With the benefit of hindsight, do you believe this reorganization has benefited or improved the overall operation of these observatories?

Answer It is hard to say whether the reorganization of the optical observatories into NOAO has benefited the overall operation of the observatories. Even in a period of major program reductions some things have been achieved for which NOAO as a whole may take some credit. Among these are the successful proposal for a solar oscillations network (GONG) whose initiation would have been more difficult within the scope of the National Solar Observatory; the completion of the Image Reduction Analysis Facility (IRAF); coordination throughout the observatories of computer acquisitions and software; the introduction of common approaches to instrumentation in the infrared and optical, some reduction in program overhead; better focusing of the technology development program for NNTT; and the initiation of some exciting and vigorous new concept studies.

At the same time the urgent need to reduce the program of NOAO has, perhaps inevitably, drawn together the partisans of the component programs of NOAO. The divisiveness thus introduced tends to favor separation of NOAO back into its component observatories. The desirability of continuing with the NOAO experiment should be closely examined in the context of a chill future funding climate. Separating the observatories will produce no more money and would arguably leave each with less, but it may at least leave the individual constituencies with a greater sense of being able to provide for their own destinies, if that is an appropriate objective.

4. **During the past two years, some general criticisms of this reorganization have been heard — such as problems with "extra layers of management" and problems in the efficient management of the more remote sites in Cerro Tololo, Chile, and at Sacramento Peak in New Mexico.**

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While such major changes are often accompanied by these kinds of concerns, can you identify some of the major achievements or advances that have been facilitated as a result of this reorganization?

Perhaps 2 1/2 years is too short a time to be able to show significant progress. If so, what do you anticipate for the future in the way of major progress for the NOAO observatories if you had the funding?

Answer The extra layer of management has the effect of freeing three observatory directors to concentrate on their internal observatory operations while one interfaces with AURA and NSF. It is difficult to respond to a statement that the formation of NOAO has led to inefficiencies in the management of CTIO and Sacramento Peak. We would be happy to respond to specific instances.

Some specific examples of major achievements that have been facilitated as the result of the reorganization are provided in response to question 3. These are of two general kinds. (1) It has been possible to stimulate promising projects through the allocation of seed money drawn from the larger total budget (e.g., GONG, adaptive optics). (2) Greatly improved coordination between CTIO and KPNO which has led to a common approach to infrared instrumentation; to the application of charged coupled devices; to software development; and to a better scientific program through a developing sense of common purpose among the scientific staff of NOAO. There is no doubt that the program aimed towards a major new national telescope (NNTT) is much more focused and forceful, and has earned wide visibility and respect in the astronomical community. This we believe has been facilitated as a result of the reorganization.

Our objectives for the future are to enhance the program of NOAO in each of our three basic program areas; support for the contemporary astronomical community; initiatives aimed at enhancing the future of astronomy; and strengthening in-house science. We must work to improve the scientific environment within NOAO to make it a far more enticing place to work, so that the National Observatories can retain or attract the quality of scientists who will best support the user community and contribute to development of instrumentation that will maintain the quality of NOAO observing facilities. Support for the contemporary astronomical community will be sought, e.g., through improvement of performance and instrumentation of telescopes; by construction of a wide-band communication link to Chile which would open up the appeal of southern-hemisphere observing to a much wider constituency; through the location of flexible computer capabilities (workstations) at the larger telescopes to allow for on-site data-reduction. We see also a central need for NOAO to address the urgent need for more and larger aperture for the U.S. community. We must also initiate efforts to study the application of promising new technology--such as wavefront correction, and interferometry.

5. **We understand there are initiatives by other countries to build new telescopes. With that in mind, do you believe that the AURA observatories have maintained a lead relative to those of Europe and Japan, for example, in recent years, or are we gradually falling behind?**

Do you think the situation could be improved if NOAO funding was increased, or are there other more significant issues like the overall health of university graduate astronomy programs, etc.?

Answer The U.S. national capability in ground-based optical stronomy is falling behind that of other countries. Thus Europe, Japan, Germany, the United Kingdom, and the USSR are planning major (inter)national ground-based optical/infrared telescopes in the 8 to 25-meter aperture class. Many of these facilities are expected to obtain funding soon. Within NOAO we are planning the National New Technology Telescope (NNTT) to stay competitive, if not keep the lead, as the U.S. national optical observatory. Working with the U.S. universities, NOAO aspires to capture the lead in the emerging field of imaging interferometry.

We are fully ready to undertake construction of a large aperture U.S. national telescope. By the end of 1986 we expect to have completed a scientific and engineering design study for an NNTT which will describe in detail the telescope structure, optics, instrumentation, and facility management and operation plan for such an addition to US astsronomy capabilities. The future health of U.S. astronomy depends vitally on a national commitment to move ahead vigorously in this area. There is nothing stopping us except NSF and Congressional approval and funding.

6. **The Fiscal Year 1987 budget request for the National Solar Observatories is approximately 16.8% greater than the FY 1986 current plan. Will this increase be sufficient to maintain Sac Peak in an "optimal manner" in Fiscal Year 1987? What is the status of the FY 1987 NOAO Program Plan?**

Answer The increase in the 1987 budget request is the Global Oscillation Network Group (GONG) project. This exciting new initiative will involve the addition of some technical positions at Sac Peak, but will have little or no effect on the current program. The Sac Peak program will continue to operate at about the FY86 level, which, although not "optimal," is at a level that will allow a productive scientific program.

The FY87 NOAO Program Plan is in preparation.

7. **To what extent is the U.S. Air Force committed to supporting the operations and maintenance of Sac Peak in Fiscal Year 1987? Does a formal agreement between NSF and the Air Force still exist regarding Sac Peak?**

Answer This question should be addressed to the National Science Foundation. It is our understanding that the U.S. Air Force is indeed committed to supporting the operation and maintenance of Sac Peak in 1987 and that a formal agreement to this effect exists between the NSF and the Air Force.

8. **It is our understanding that the management of NOAO continues its research into the development and eventually construction of a 15-meter National New Technology Telescope (NNTT) similar in many ways to the Keck Telescope.**

The Fiscal Year 1987 budget request for most Federal agencies, including NSF, is predicated on the basis that there will be no new starts for

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major capital projects. The actual construction of NNTT has, of course, not been started although several million dollars have already been expended. In light of the construction of the 10-meter telescope combined with the budgetary constraints on already existing Federally supported astronomical facilities, would these facts negate the need for a new technology telescope? Or do these facts in any way push back the need for a new technology telescope? Wouldn't we be better off using our existing resources to maintain or expand our existing facilities in an "optimal manner"?

Answer These questions might also be addressed to the NSF. Last year the NSF appointed a study group, headed by Dr. Robert Kirshner, which we understand has considered these issues, among other matters. We also understand that the report of this study group will be presented to the NSF Advisory Committee on Astronomical Sciences late in April. While we are not privy to its content, we hope the following comments from our perspective will be useful to the Committee.

The NNTT is very different from the Keck telescope in many ways. The NNTT uses a technology which was tested and convincingly demonstrated on the Smithsonian/University of Arizona Multiple Mirror Telescope (MMT). In this technology the light from a number of separate telescopes (six for the MMT, four for the NNTT) is combined in a single coherent image rather than using a single segmented mirror telescope as is the case for the Keck telescope. The advantage of the MMT/NNTT technology lies in the smaller telescope size for a given collecting area, its larger angular resolution especially in the infrared, its larger field of view, and its better match to its (spectral analysis) instrumentation. The NNTT exceeds the capabilities of the Keck telescope both in collecting area (more than twice), in its image sharpness especially in the infrared (four times the number of pixels) and in its sensitivity (almost ten times larger in the infrared). The NNTT will use a technique to compensate for atmospheric image distortions in the infrared called adaptive optics. This technique, developed initially for military use, is now being tested on existing NOAO telescopes. If successful, it will increase the image sharpness and sensitivity especially at short infrared wavelengths a hundredfold. The NNTT is different from the Keck telescope in other ways as well. It will be a National Facility available to all U.S. astronomers. We might consider an exchange agreement with the European Southern Observatory (ESO), which plans to build a 16-meter telescope array in the southern hemisphere, to make time available to U.S. astronomers on the ESO facility.

The gains in capabilities of the NNTT over the Keck telescope are very substantial. The gains in collecting area and angular resolution should be compared to those achieved in the 30 years that passed between the construction of the Mt. Wilson 100-inch and the Palomar 200-inch telescopes and the 40 years between the 200-inch and the 400-inch Keck telescopes. Certainly the relatively short delay associated with the current budgetary crisis fades in this comparison. This delay will however effect the longstanding leadership status of U.S. astronomy in the world which was initially won with the construction of the 100-inch telescope.

AURA maintains its current facilities in optimum condition. It has been expanding their capabilities by improved detectors and instrumentation. Major strides in detector technology have been made in the past decade. Detectors are, however, reaching their ultimate limits of sensitivity. It is exactly for that reason that many astronomers need larger telescopes to make further progress.

Finally, we believe that NOAO must continue to emphasize the future of the discipline if it is indeed to play any role in that future. In no respect is this more important than in the provision of large new telescopes. This message is clearly articulated by the groups, both within and outside the U.S. who are committing large sums and major human resources to satisfy this need.

9. **What will be the role of the AURA observatories in relation to the Hubble Space Telescope? It was reported in the *New York Times* that the Keck telescope will be able to conduct observations far beyond the reach of the Space Telescope. I should point out that the Space Telescope is expected to cost 17 times more than the privately funded Keck Telescope. With that in mind, can you briefly sort out for us the specific advantages the Space Telescope will have over these more powerful ground-based telescopes?**

How is AURA helping NSF and NASA to set research priorities and to coordinate operations for ground-based and space-based astronomy in the period following a successful launch of the Hubble Space Telescope?

Answer The Hubble Space Telescope (HST) is unsurpassed in its ability to achieve high spatial resolution imaging and to work to faint limiting magnitudes in the ultraviolet part of the spectrum. It will be particularly valuable for studies of the stellar populations in nearby galaxies, and for such problems as establishing the distance scale by resolving variable stars in crowded fields in other galaxies, studying protoplanetary disks around young stars, etc. Ground-based telescopes remain the instrument of choice for problems that benefit from larger aperture. In particular for extended objects but also for faint point sources, there is likely to be very substantial demand for both high and low resolution spectroscopic observations of objects imaged by HST. For equal-length exposures and for the expected angular sizes of galaxies at large redshifts, 4-meter class ground-based telescopes will out-perform HST even for imaging.

Because the capabilities of HST and large ground-based telescopes are complementary, astronomy will progress most rapidly if observations can be coordinated. At the request of NASA and NSF, representatives of ST ScI, NOAO, NRAO, and NAIC met recently to discuss ways to deal with the problems of coordinating ground-based and space observations. Mechanisms were established to handle the scheduling of programs that require simultaneous observations with two or more different facilities, but these mechanisms will be adequate only if the demand is small.

The coordination of space and ground-based programs does place new requirements on ground-based facilities that cannot be easily accommodated by existing facilities. The problem is particularly acute for optical telescopes, where we expect the demand for supporting spectroscopic observations to be very high. New facilities may be required to meet this demand. Specifically, several groups of astronomers who have considered this issue, formally and informally, have recommended construction of two new 4-meter telescopes, one in each hemisphere, that would be dedicated to support of the space program. Emphasis would be on spectroscopy, with high and low resolution multi-object spectrographs mounted permanently at the Nasmyth platforms, with a CCD imaging device at the Cassegrain focus. The telescopes would be designed to allow for quick instrument changes, and most programs would be carried out through queue scheduling and service observing. This kind of flexibility, which is essential for full and effective support of space observations, can very likely only be achieved with new designs for telescopes and new approaches to operating them.

10. **The National Aeronautics and Space Administration (NASA) did not request funding this year for the Solar Optical Telescope (SOT) project. How do you see this affecting the balance between ground-based or space-based observations of the sun?**

Answer A solar space telescope with an angular resolution comparable with that of the HST is critically needed to make progress in major areas of solar research. The NASA Solar Optical Telescope (SOT) was such a telescope. Its elimination is a severe setback for this important area of astronomy. It will shift the balance of high resolution solar research to ground-based telescopes where the emerging technique of adaptive optics will allow us to push somewhat ahead although not reaching the capability of the SOT. While the U.S. solar community was basing its plans on the SOT, the European solar community moved ahead with the planning and building of ground-based facilities in excellent locations in the Canary Islands. The U.S. lead in high resolution solar physics was therefore lost by the elimination of SOT and will be hard to recapture.

11. **The Large European Solar Telescope (LEST) organization has expanded to include other countries, including the United States. Do you believe that the United States should settle on supporting the construction and operation of a new, high resolution solar telescope together with many other countries, or should AURA try to promote an equivalent exclusively U.S. instrument?**

Answer The LEST instrument will represent a new generation of high-resolution solar telescopes; United States participation would ensure our place in advanced, high-resolution solar research; we are likely, otherwise, to lose our lead in this area--unless we build and operate our own instrument. We already have a lead in active optics--an important element of the new generation of solar telescopes--and we should continue to pursue this avenue vigorously as well.

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Mr. **Boehlert**. Dr. Murino, I just would like to know how far along you think we are with respect to answering the major questions on the causes of acid precipitation—not all the questions; just the major ones.

Dr. **Murino**. I think we are part of the way there when you say how far along; we still have to work to couple the atmospheric chemistry processes that are going on with the atmospheric circulation processes that are going on, and that is fairly difficult.

NCAR is undertaking quite an ambitious program addressed to precisely that issue. I think we have made major progress in that area. I think, for the first time, we have got a good coupled acid precipitation model, so I think we have made progress there, and this will be particularly important when one looks at the regional effects of acid precipitation or local effects; for example, the concerns that you have in your own State of New York.

The global picture: we are still some distance from that. So, with respect to your question, or in answer to your question, we are well along in the regional area in coupling these models, but the global matters, not yet.

Mr. **Boehlert**. Well, the data base on a sensitive issue like this, particularly one dealing with our environment, is never adequate or complete. But would you agree with the National Academy of Sciences, which said 2 years ago that we have enough information to proceed with an action plan, in addition to further studies? You see, part of the problem is: those who are out there opposing any meaningful action plan at this point say that they are just as concerned about the environment as I am, for example, but they argue that we don't have enough information to proceed.

Then I listen to people like Governor Kean, of New Jersey—I thought he had a great statement—he said: "If all we do is study the problem, we will end up with the best documented environmental disaster in history."

We have got to continue the study, but don't we have enough information to go on?

Dr. **Murino**. We are very close to that point now; perhaps in less than a year we should be in a position.

So, that's my own judgment. I am really not an expert in that area, Mr. Boehlert, so I think you might talk to others that are specialists in the field to get the precise timing.

But my feel for it, and in discussions with them, is that we are getting very close to that now.

Mr. **Boehlert**. Thank you very much.

Mr. **Walgren**. Thank you, Mr. Boehlert.

They have signaled a vote on the floor of the House, and I think, as a practical matter, if you folks would make yourselves available to written inquiries from the committee, we can explore for our purposes the areas that remain open; and since three of you are from Washington, and, Dr. Murino, you get to Washington a good deal, please know that the committee would like to know of your concerns as they arise, and we certainly are available to you as well.

So, we appreciate your being available to us and hope to return that by being available to you.

Thank you very much.

[Whereupon, at 12:30 p.m., the subcommittee adjourned, to reconvene at the call of the Chair.]

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1987 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

WEDNESDAY, FEBRUARY 26, 1986

House of Representatives,
Committee on Science and Technology,
Subcommittee on Science, Research and Technology,
Washington, DC.

The subcommittee met, pursuant to notice, at 2:15 p.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Mr. Walgren. Let me welcome you to the committee this afternoon. We begin the third and final hearing on the National Science Foundation authorization for fiscal year 1987.

In the two previous hearings testimony was given from officials of the Science Foundation itself, as well as representatives of various scientific and professional societies and research organizations. Their testimony is certainly helpful to the committee in its review. It helps us better understand the trends and the issues in basic science and engineering research.

Today we have two panels that will focus on specific activities within particular scientific disciplines. Each witness brings a highly respected expertise in his or her field of study.

The first panel is comprised of Dr. Jon Fuller, the president of the Great Lakes Colleges organization; Dr. Andreas Paloumpis—is that close to right? I apologize if it is not—president of Hillsborough Community College in Tampa, FL; and Mr. Joel Bloom, the director of the Benjamin Franklin Institute in Philadelphia, PA. These gentlemen will focus on science and engineering education.

And then we have a second panel to deal with a number of scientific disciplines that have been the subject of study by special committees of the National Academy of Sciences and the National Academy of Engineering. These witnesses will be Dr. Dale Compton, the chairman of the National Academy of Engineering Panel on Engineering Research Centers; Dr. Harry Gray, a member of the National Academy of Sciences Committee To Survey Opportunities in Chemistry; Dr. Neil Smelser, the cochairman of the NAS Committee on Basic Research in the Behavioral and Social Sciences; Dr. Edward David, chairman of the National Academy of Science Committee on Resources for the Mathematical Sciences; and Dr. Thomas Malone, the past chairman of the National Academy of Sciences Board on Atmospheric Sciences and Climate.

On behalf of the subcommittee, I want to thank all of you for the preparation that has gone into these hearings. I keep having this vision of the "Tonight Show," where the woman that substitutes for Johnny Carson at some point leans over and says, "Can we talk?" Along that line, I want to encourage all the witnesses to feel free to just talk, as opposed to reading more detailed statements, because the real value in this presentation is both to give an outline to interested observers of the committee, but also to give us an oral record which will focus attention that then can be brought to reading the written statements which will be reprinted in full in the hearing record, and therefore there in all their detail for people who would go back and look at these issues and what is said about them.

So please feel free to summarize and, in view of the numbers of witnesses this afternoon—eight or so—know that something in the range of 10 minutes on the outside is probably what we should deal with, in deference to the other witnesses and the possibility of interruptions by voting on the floor of the House. So, with that, let me invite you to proceed in the order in which I introduced you, and we will have all three of your statements and then see if there is some range of discussion we would like to pursue. But, as I say, please feel free to summarize and just talk.

OK. First, then, Dr. Fuller.

STATEMENT OF DR. JON FULLER, PRESIDENT, GREAT LAKES COLLEGE ASSOCIATION

Dr. **Fuller**. Thank you, Mr. Chairman. I will take that invitation.

In the original authorization for NSF, the Foundation was given two major responsibilities. One which it has performed consistently and very well is the support of basic research. The other, which has been more erratic in its performance, has been providing for our future scientific capacity through the support of science education.

We are pleased at this point, after a period of what we saw as serious and really dangerous neglect, the Foundation seems to have renewed its commitment to that second part of its mission, to science education. The undergraduate years, which are the focus for my interest and my remarks today, are we think a really crucial part of that continuous process of science education. That's the last point at which we can attract qualified students to a career in science. It also is unfortunately the last point at which we lose a significant number of prepared students who decide not to pursue a career in science.

Right now, although every projection says we need more scientists and technicians and teachers of science for the future, we are in fact encountering a dropoff in the numbers of students and the percentage of students pursuing science majors. The colleges that I work with specifically—as you know, Mr. Chairman, having attended the conference at Oberlin last summer—feel proud that in fact our numbers have not declined, but we do have a general issue in science education and a set of problems that we need to address. That includes, I think, supporting the strength which some of those institutions that have been able to maintain their productivity have shown up to now.

Attached to my testimony is some data which shows productivity for science Ph.D.'s, adjusted for institutional size. If you will scan that list, you will see that a significant number of primarily undergraduate institutions are among the most productive in our country. That data was prepared by Dr. Carol Fuller of our staff, who is with me today here.

For undergraduate institutions, the top priority—this was identified by the ACE task force this fall, and from every account we can get it is going to be confirmed by the National Science Board's Committee on Undergraduate Science—is for instrumentation. There are two NSF programs that promise us some help in those terms.

One is through the Research in Undergraduate Institutions Program, which does provide instrumentation support related to research projects, and that in some ways, for many of these undergraduate institutions, is the most valuable part of that program these days.

The other is the College Science Instrumentation Program. That had very heavy proposal pressure last year—a lot of very good ideas and proposals which couldn't be funded at the existing appropriations level. We were pleased by the accounts that NSF was going to request additional dollars for that program for this next year, but have been a little concerned to see that in fact there is an intention to designate a significant part of those dollars—about $3 million—to go exclusively to engineering institutions.

I acknowledge that engineering is very important, but we would like to see those hard decisions—and we realize they are hard rationing decisions—made in an open, peer-reviewed process, an open competition, rather than sequestering certain portions of them for one sector. At least we don't think the need there, the acute need, has been demonstrated. It's a need across the spectrum of institutions.

Mr. **Walgren**. That's $3 million out of how many million? How big a program is that?

Dr. **Fuller**. It would be $3 million out of a little over $7 million. It would leave $4.5 million this next year for the College Science Instrumentation Program. Last year we had about $5.5 million available, and that was very insufficient for the proposal pressure.

Mr. **Walgren**. And what was the other NSF program?

Dr. **Fuller**. The other one from which we can get help with instruments is the Research in Undergraduate Institutions Program. You make a research proposal, at least part of which requires funding for instrumentation; and although the proposal has to be focused on a specific research project, one of the glories of these undergraduate institutions is that once they get a piece of equipment, they will use it night and day in instruction as well as research. It gets very good usage.

Mr. **Walcren**. Thank you.

Dr. **Fuller**. One of the other advantages of that College Science Instrumentation Program which we think has been a real plus as it has been administered has been that it requires a matching contribution by the institution. It's a way of leveraging the Federal dollars, we think very helpfully, and also a way of rationing. You only are getting the dollars going for instruments where the institutions agree they really need them.

The second priority for undergraduate institutions involves research opportunities for the scientists who teach in those institutions. That exists now primarily through the Research in Undergraduate Institutions Program, and we have been very appreciative of Mr. Bloch's support of that program and of its growth. We do find, however, that because it is decentralized—it is not administered by a single unit at the Foundation, but rather involves all of the directorates, depending on the particular focus of the research proposal—we get very uneven treatment of undergraduate college proposals.

In some directorates we get complete understanding of the fact that these proposals may be scientifically as good, but they are going to have an involvement of undergraduates, ideally, and they are also going to be coming from somebody who spends most of his or her time teaching rather than doing research, and so they are not going to be turning out the number of articles every year that you get from somebody whose primary mission is research. Some of the directorates are understanding about that but, unfortunately, some of them are not, and we get not only misunderstanding but even hostility out of some of them still.

We hope that you will join us in pressing NSF to see that we get better accountability in the administration of that program in the future. It is a valuable one and we certainly do appreciate it.

As I said, when you get research done by a scientist at an undergraduate institution, you get undergraduates involved; you get quality research; and indeed sometimes, because it is done often by a more senior researcher actually doing his own work, not managing graduate students, you get a different quality of work.

Mr. **Walgren**. Let me ask you to pull the mike in a little bit, so it might project in the back of the room as well.

Dr. **Fuller**. One other aspect which is related to this has been the specific provision of research opportunities for undergraduates. I am very pleased to see Mr. Bloch recently acknowledged that that is extremely important, for undergraduates to have a hands-on research experience, to really solidify their commitment to a science career choice.

We used to have a program at NSF called undergraduate research participation, which the Foundation unfortunately abandoned. They now seem willing to revive it in some way. I understand they are proposing to administer it, also, through the research directorates.

I think there is some question whether that is the right focus in that particular case because, while it is research experience, the primary purpose of it is not the merits of the research but the educational experience for the undergraduate who is participating. That is why we would think that that would be appropriate, in that case, to involve the Science and Engineering Education Directorate which previously administered the URP Program and did it very well.

I might add, Mr. Chairman, that our Great Lakes Colleges Association and the Associated Colleges of the Midwest are currently doing a survey of undergraduates—now graduates of our institutions—who participated in the URP Program, to determine what impact that had on their career development. We will have that data later this spring, and we will certainly provide it to this committee and to the Foundation.

The anecdotal data we have at this point simply confirms what we frankly expected, and that is, it really has a very important influence, to actually have that opportunity for hands-on research experience. It confirms the thrill of science for those students and does make sure they carry on with that scientific career. It's not an easy choice, as you know, and far too many people drop out. If they have had the taste of success as undergraduates, they are more likely to continue.

There is one other need which we do have at the undergraduate institution which isn't true of our research colleagues as much, and that is for broader professional development opportunities for a scientist who teaches undergraduates, because he or she teaches a broader range of courses, not just one specialty but basic introductory science. As those fields change rapidly, there is a need for people who teach in those institutions to be able to keep up with the field more broadly.

We used to have, again, a program called the science faculty fellowships which filled that need very well, and we think that particular model is worth looking at again. The National Science Foundation does offer new research opportunity awards, which are helpful. That allows an undergraduate faculty member to be joined into an existing research project, often at a major laboratory, for a period of work. That is useful, and they are now advertising that much more vigorously. We appreciate that, but we think that some other, simply broader, professional renewal opportunities are also very worth considering.

In closing, I want to make one point about the adminstration of the Foundation. There are very few scientists from undergraduate institutions serving on the advisory committees and the review panels of the Foundation. Mr. Bloch has acknowledged that we need to increase that representation, but the actual progress has been painfully slow. In fact, unless you have at the table where decisions are being made, a firsthand understanding of science in undergraduate institutions, you are often not going to get the appropriate level of support for that vital sector of science.

The National Science Board presents a particular problem. When they created, with the urging of the House of Representatives, a Committee on Undergraduate Science this last spring, they found that there was no one on the National Science Board with firsthand experience with undergraduate science, and so they had to bring in an outside member—I know you know President Powell of Franklin and Marshall—to serve with them as a sort of adjunct member, in order to provide the firsthand knowledge they needed to do their work.

We think they need a set of people from those colleges—with undergraduate experience—on the National Science Board, so that that dimension of the Foundation's interests and of our national science interests aren't neglected in the future in the way that they were for a period in the recent past. We hope that this committee will join us in urging NSF to see that that happens.

We appreciate your interest in undergraduate science; your personal support, and the support of your staff; and we appreciate Mr. Bloch's renewed emphasis on it, as he has become director. We think we are on the right track. We have some ideas about how to move it a little faster, but we certainly would say that what is happening already is good and that there is a considerable need out there. It's important. We are glad it is being recognized, and there is more to do.

Thank you, sir.

[The prepared statement of Dr. Fuller follows:]

Statement on Science at Undergraduate Institutions,

delivered by President Jon W. Fuller of the

Great Lakes Colleges Association

Mr. Chairman:

I am Jon Fuller, President of the Great Lakes Colleges Association. I am pleased to have been invited to appear before this committee as you consider reauthorization of activities of the National Science Foundation. In appearing here today, I am representing the twenty-five liberal arts colleges which are members of the Great Lakes Colleges Association and of the Associated Colleges of the Midwest.* Reed College in Oregon and Connecticut College also join in supporting our position, as do the 370 members of the American Association of State Colleges and Universities.

The original authorization of the National Science Foundation gave it a dual responsibility both to support the most promising basic research and also to provide for our future scientific capacity through the support of science education at the undergraduate and pre-college levels. Our national security and our economic well-being rest on our continued excellence, both in current research, and in development of an adequate number of scientists, teachers of science, and technicians for the future. We are pleased to see that, after a period of serious and dangerous neglect, the National Science Foundation has renewed its commitment to this second part of its mission, "the development of properly educated and trained people, the human resources pool that provides the scientists and engineers for the future," as the NSF Director, Mr. Bloch, aptly put it in introducing the Foundation's fiscal 1987 budget proposals.

It is extremely important that the process of science education and the education of scientists be seen as continuous. The undergraduate years represent a crucial phase in this process, the last point at which qualified students can chose careers in science—and unhappily, the time during which significant numbers of qualified students are chosing not to pursue careers in science. A declining proportion of American undergraduate students express an intention to major in science, and each year fewer baccelaureates are being awarded for the completion of science majors. This is happening at a time when every projection of our future needs indicates that we will need larger numbers of scientists, teachers of science, and appropriately trained technicians to sustain our scientific and economic activity. This decline in interest in scientific careers extends to the graduate schools, where we have seen a significant drop in the number of new Ph.D.'s they award each year in the physical sciences, mathematics, and engineering. A real danger to us as a nation is the fact that the number of American citizens among those science Ph.D.'s has declined even more sharply than the total numbers would suggest. An increasing proportion of the graduate school enrollment in the sciences and particularly in engineering is now made up of foreign nationals. As NSF Director Bloch recently put it there is a real danger that pursuing a Ph.D. in the physical sciences and engineering is "becoming an un-American activity!"

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*The Great Lakes Colleges Association is a consortium of twelve undergraduate liberal arts colleges: DePauw, Earlham, and Wabash in Indiana; Albion, Hope, and Kalamazoo in Michigan, and Antioch, Denison, Kenyon, Oberlin, Ohio Wesleyan, and The College of Wooster in Ohio. The Associated Colleges of the Midwest includes thirteen undergraduate colleges: Colorado College; Knox, Lake Forest, and Monmouth in Illinois; Coe, Cornell, and Grinnell in Iowa; Carleton, Macalester, and Saint Olaf in Minnesota, and Beloit, Lawrence, and Ripon in Wisconsin.

The colleges which I specifically represent, and others like them across the country, take pride in the fact that our science enrollments have not declined. We also take pride in the continuing contributions of these institutions in sending their graduates on to complete Ph.D.'s in the sciences. That contribution is particularly striking when one takes account of the smaller institutional size of most of these colleges, compared to the large universities. I have attached to my testimony a summary of recent research by Dr. Carol Fuller of our staff which identifies the most productive undergraduate sources of Ph.D.'s as measured by the percentage of their graduates going on to complete those degrees.

One response to this situation must be to support the success of these colleges which have managed to sustain undergraduate interest in the sciences. But it is also important to look at the undergraduate experience across the whole spectrum of higher education institutions, and to strengthen the quality of science instruction during those very important four years.

Because the production of scientists, teachers, and technicians is a continuous process, science instruction in the elementary and particularly in the secondary schools must also command our attention. The colleges with which I work most closely are finding a great range in the quality of preparation in mathematics and science among freshmen who come to us. Some of it is really very good. But the overall grade must still be rated as "poor." A significant part of the problem is that we are losing qualified secondary school science teachers, drawn away by larger salaries and more attractive professional opportunities. A significant part of the responsibility for dealing with the situation in our elementary and secondary schools certainly lies at the local and state level. That is particularly true in terms of trying to deal with the difficult issues of appropriate levels of compensation for teachers generally, and specifically for those in fields like the sciences and mathematics. But the federal government can have an important and useful role in upgrading and sustaining the qualifications of those who do chose careers in teaching science in our elementary and particularly in our secondary schools. In-service and summer institutes, now being sponsored by NSF, are certainly useful. Cooperative links between schools and colleges and universities are also very helpful, and we hope that NSF will be more active in encouraging and supporting those kinds of linkages. Because such an important part of the problem seems to be sustaining the sense of professionalism for teachers of science, we need to look carefully at programs of recognition and encouragement for these important people. One promising development, now being supported on a very experimental basis by NSF, involves including secondary teachers in research activities in colleges and universities, particularly during the summer, as a way of recognizing and sustaining their commitment as scientists.

Let me turn now to the specific needs at the undergraduate level. As you know, with direct encouragement from the House of Representatives, the National Science Board established a committee early this summer to address problems of science at the undergraduate level. In the initial charge to that group, the chairman of the National Science Board, Dr. Roland Schmitt, acknowledged that "currently no systematic federal leadership or support exists for science, engineering and mathematics education at the undergraduate level." We await the report from the National Science Board next month. But we already know that an important part of their deliberations was the contribution of the Higher Education Associations' Task Force, which was coordinated by the American Council on Education. In that group's report, the first priority was placed on the need for instructional scientific equipment and materials. The experience of the colleges with which I work most closely confirm that priority. Both research and instruction in sciences increasingly requires equipment which reflects the rapidly advancing "state of the art." Helping institutions to aquire this desperately needed equipment represents a very productive use of federal resources.

The National Science Foundation now offers two programs which can assist colleges and universities in meeting their equipment needs. The first of these is the College Science Instrumentation Program. There have been far more quality proposals to this program than it has been possible for NSF to fund. We are therefore very pleased that NSF is proposing a $2,000,000 increase for CSIP for fiscal 1987. I certainly hope that increase will receive congressional approval. We understand that in this next year, NSF intends to focus the increase particularly on the needs of engineering schools. Frankly, we would prefer to see the program continue to be open to all kinds of institutions on a fully competitive basis, with the increased funding going to those places presenting the best proposals. We certainly don't deny that there are needs in the engineering field, but there are needs which are not being met across the institutional spectrum, and we believe that a competitive peer review is still the best way to make hard choices. An important feature of the CSIP grants is their requirement of matching dollars to be raised by the institutions. This also represents a very useful way of extending the value of the federal investment.

It has also been possible to support research instrumentation (which at any good undergraduate college always has instructional uses as well) through the research directorates' funding of proposals under the Research in Undergraduate Institutions Program. Instrument support has been one of the most valuable products of this program, and we certainly hope that it will be sustained.

A second need for undergraduate institutions is research opportunities for their scientists. This is now being provided primarily through NSF's Research in Undergraduate Institutions Program. Frankly, there have been some problems because of the highly decentralized nature of this program's administration. Some directorates have been very responsive to RUI priorities, while staff and reviewers in other parts of the agency continue to reflect not only a lack of understanding but even hostility to the idea that good research can be done by scientists whose primary focus is on the teaching of undergraduates. We hope that this committee will join us in continuing to press NSF leadership for accountability in actually delivering on the promises of the RUI program.

Support of research being done by faculty members who are actively engaged in teaching undergraduates simultaneously produces good and needed research results and also uniquely important education for future scientists. The research done by scientists at undergraduate institutions can be just as good as that done in any setting across the country. Because of its scale and pace, research conducted at undergraduate institutions can make uniquely valuable contributions to science. It is important, however, as the RUI guidelines try to make clear to reviewers and staff members, to recognize that work done by a scientist with major undergraduate teaching responsibilities must inevitably come at a slower pace and that the quantity of published results will be less, although the quality can be competitive with that of scientists whose primary responsibility is research.

There is another advantage in research which is done by scientists at undergraduate colleges: it is typically carried out as an extension of teaching, involving the most promising undergraduates. This is one of the reasons that support of research by faculty at undergraduate teaching colleges has a double value: the quality of the research itself, and the contribution it makes to the education of some of our best future scientists. In background materials done for a conference held at Oberlin last summer, which brought together 48 good liberal arts colleges with a strong record in science productivity, it was noted that the science faculty at those institutions had produced approximately 7,000 articles in the past 5 years, and that a third of those had been co-authored with undergraduates.

One of the most valuable programs of the NSF's Science Education Directorate was the Undergraduate Research Participation program. Unfortunately, it was abandoned by the agency several years ago, as part of their effort to shed that important part of their overall mission. As that trend is being reversed at NSF, we are pleased that funding for undergraduate research participation is back on the agency's agenda. We wonder why the Science and Engineering Education Directorate is not being called upon to administer this program, with the education of undergraduates as its principal purpose; URP was an exemplary program, both in review and operation, when it was operated under that aegis earlier. The fiscal 1987 budget summary mentioned plans to support bringing together "small groups of students to participate in the conduct of research." There appears to be an interest in having that take place at major research laboratories, and that certainly is one appropriate way of organizing undergraduate research opportunities. It is also important to fund such activities at undergraduate campuses, so that some of the research work can go on during the academic year, and not just in the summer as part of a special program. As Mr. Bloch has noted, "once students enter their third or fourth years, the best way to prepare them to undertake graduate work is by increasing opportunities to participate in research activities."

The Associated Colleges of the Midwest and the Great Lakes Colleges Association are currently conducting a survey of past participants in the URP program, to identify the influence of that experience in their subsequent careers. When that survey is completed, we will certainly report its findings to this committee as well as to the Foundation. The preliminary and essentially anecdotal results are, not surprisingly, a strong endorsement of the value of research experience during the undergraduate years.

It has been possible to support undergraduate research experience as part of the RUI program. There has been great unevenness in the agency, however, in the degree of understanding by staff and reviewers about the value of that element of any research proposal.

The NSF is on the right track in its plans to resume support for undergraduate research participation. We hope that this will have your committee's full support. It represents an important and definitely cost-effective investment in our future scientific resources.

One area which is still not being adequately addressed by any NSF efforts involves the broader professional development of science faculty members who teach at undergraduate institutions. Opportunities to do research are an important part of professional development for those scientists whose primary responsibilities involves the teaching of undergraduates. But they also need periodic opportunities for professional renewal. They need to work with and consult with scientists at larger laboratories, as a supplement to the research activity which they can carry on there and on their own campuses.

Faculty at undergraduate campuses are called upon to teach a broader range of courses than are colleagues at larger and more specialized institutions, and they have special needs to keep up with a wider field of knowledge. The Science Faculty Fellowships at one time filled this need by providing faculty, who did not teach in research institutions, with support to spend time in an academic or industrial research setting working on projects directly related to improving their teaching. We are pleased to see NSF recognition of this need in the fiscal 1987 budget summary, which included a promise that "traditional activities such as research sabbaticals, participation in industrial research, and special short courses and workshops will be supported." The Research Opportunity Awards, which are being advertised more vigorously by NSF, provide one type of opportunity for faculty members at undergraduate colleges to have the professionally renewing experience of being part of research activities at a larger research laboratory. But more general and flexible support is also needed. We hope that NSF and this Committee will look carefully at the successful programs of the past—particularly the Science Faculty Fellowships—as models for the ways to carry on this important element in the support for undergraduate science.

For next year, the NSF is proposing a new program, focused on the needs to recruit larger numbers of minority students into the sciences, which will involve funding of Minority Research Centers of Excellence. We think this idea, successful in the past as Resource Centers for Science and Engineering, has promise to be extended to other undergraduate institutions in the future. The general idea is to provide sustained NSF support to build on areas of existing strength. Those can then be used as models and resources by other institutions whose programs are still building.

We are gratified that NSF has in its budget document noted its intention to serve some of the needs of undergraduate science education. We eagerly await details and reassurances about the administration of these intitiatives. The Science and Engineering Education Directorate has useful connections with the undergraduate community. Their involvement could contribute to the success of these initiatives, as proven by the popular College Science Instrumentation Program (CSIP).

We believe that this Congress and the Foundation should also look seriously at the possibility of a program of challenge grants to assist institutions in raising the significant capital which is needed to restore various facets of the undergraduate scientific base. Such challenge grants have worked very well at the National Endowment for the Humanities. They provide excellent leverage for the Federal dollars invested. The general purpose of fundamental support for facilities and laboratories seems one particularly appropriate use for this broad kind of Federal grant support.

One general point about the operations of the National Science Foundation and its responsiveness to the needs of undergraduate institutions needs to be made: the Foundation's advisory committees and review panels include very few scientists from undergraduate institutions. It seems clear that many of the problems in the actual execution of NSF's new and welcome efforts to assist undergraduate education come from a lack of understanding about the realities of science in such institutions. The Director, Mr. Bloch, has publicly acknowledged the need to increase significantly the numbers of scientists from undergraduate institutions who serve on these committees and panels. But actual progress seems painfully slow, and this is a real impediment to carrying forward the Foundation's new and very important emphasis on the undergraduate sector of the scientific enterprise.

A particular concern is the membership of the National Science Board. When that group, with urging from the Congress, turned its attention to undergraduate science early last summer, it was necessary to recruit an outside member for their committee (President James Powell of Franklin and Marshall College) because no member of the National Science Board had direct experience with science at undergraduate institutions. It is clear that President Powell made a vital contribution to the work of that group. The continued presence of scientists with undergraduate college backgrounds in the deliberations of the National Science Board would ensure that we do not again see this important part of the Foundation's mission neglected, and that the efforts to carry it forward are indeed appropriate and effective. We ask this committee to urge the National Science Foundation to see that appropriate candidates are nominated to fill a certain proportion of the seats on the National Science Board, so that this gap in its membership experience is filled. Please also press NSF to carry through on the commitment to add scientists from undergraduate institutions to the other Foundation advisory committees and review panels as well.

We are delighted that this committee and the National Science Foundation have, by their renewed attention to issues of undergraduate science, joined in bringing about important and overdue changes in emphasis and priority for our federal science policies. We are prepared to cooperate in any way we can to provide you with the information you may need to evaluate this aspect of the National Science Foundation's mission as you consider reauthorization of its activities for the years ahead.

I would be happy to answer any questions which members of the committee may have.

Attachment

Leading Undergraduate Sources of Science Ph.D's, Adjusted for Institutional Size

Institution	Total	Ratio
California Institute of Technology	1781	39.2
Harvey Mudd (CA)	247	39.1
Reed (OR)	766	20.0
Massachusetts Institute of Technology	5141	19.9
Chicago (IL)	2592	16.6
Swarthmore (PA)	975	14.4
Cooper Union (NY)	586	13.4
UC-San Diego (CA)	325	12.4
New College of the U. of South Florida	48	11.7
Haverford (PA)	415	11.4
Webb Institute (NY)	47	11.2
Rice (TX)	1192	10.8
Harvard (MA)	3527	10.3
Oberlin (OH)	1347	10.3
Pomona (CA)	713	9.2
Brandeis (MA)	578	8.7
UC-Riverside (CA)	709	8.7
Carleton (MN)	631	8.7
Eckerd (FL)	77	8.5

Leading Undergraduate Sources of Science Ph.D's (continued)

Institution	Total	Ratio
Rensselaer Polytechnic Institute (NY)	1819	8.5
Wabash (IN)	324	8.4
Amherst (MA)	642	7.9
Cornell U. (NY)	4213	7.9
Antioch (OH)	620	7.8
UC-Irvine (CA)	253	7.8
Johns Hopkins (MD)	1207	7.8
Polytechnic Institute of New York	935	7.6
Princeton (NJ)	1765	7.6
Grinnell (IA)	450	7.3
Wesleyan (CT)	511	7.2
Carnegie-Mellon (PA)	1422	7.0
New Mexico Institute of Mining	111	7.0
Kalamazoo (MI)	307	6.7
Columbia (NY)	2553	6.6
Yale (CT)	1996	6.5
UC-Santa Cruz (CA)	192	6.4
CUNY: City College (NY)	4990	6.2
SUNY: Stony Brook (NY)	597	6.2
Wooster (OH)	527	6.2
Case Western (OH)	1751	6.0
Philadelphia College of Pharmacy (PA)	252	6 0

Leading Undergraduate Sources of Science Ph.D's (continued)

Institution	Total	Ratio
Stanford (CA)	2401	6.0
Williams (MA)	507	6.0
Bryn Mawr (PA)	276	5.9
Earlham (IN)	308	5.9
Franklin & Marshall (PA)	554	5.9
Brown (RI)	1388	5.8
Radcliffe (MA)	469	5.8
New School (NY)	57	5.6
Stevens Institute (NJ)	359	5.6
Worcester Polytechnic (MA)	400	5.6

Ratio=average science Ph.D's divided by average baccalaureate degrees awarded.

Science Ph.D. totals reported by the National Academy of Sciences. Sciences include Empirical, Life, and Social Science fields.

Baccalaureate totals reported by the National Center for Educational Statistics and the American Council on Education.

Calculations based on Ph.D's conferred, 1951-1980, and bachelor's degrees awarded, 1946-1976.

(In a few cases, the numbers reported here differ from previously published numbers because of adjustments in baccalaureate data.)

Mr. Walgren. Thank you, Dr. Fuller.

If my colleague would permit, I just wanted to make a comment at this point in the record about how striking it is that you say that there are not very many undergraduate scientists reviewing the whole range of peer-reviewed work in the NSF, because we hear time and time again, whenever you open the door, the reaction that much of the peer review system is an old boy network.

We have talked with the National Science Foundation about how to get more independent panels and even whether or not you should go to nonscientists, if you had some assurance that they could appreciate the value of the science involved, so that the judgment is then made on the value of the science and not the origin of the proposal or the like. It would seem the first place you would turn if you wanted a sensitive scientific judgment would be to science professionals who are in the undergraduate institutions because they, first off, would be extremely able to judge the value of any particular incremental progress in any discipline. So——

Dr. Fuller. I think that is absolutely right, sir. We have been trying to provide some names, and some of them have been taken, but it seems to move pretty slowly. Anything you can do to urge the Foundation to move along in that direction would be very helpful.

Mr. Walgren. Well, thank you very much.

We have been joined by the ranking minority member on this committee, Mr. Boehlert, and I would like to recognize him now for any comments he would like to make.

Mr. Boehlert. Thank you, Mr. Chairman. First of all, my apologies to the distinguished panel. I have the benefit of your testimony. It will be very carefully examined. We have professional staff here that will follow through but, as is so often the case on Capitol Hill, we are supposed to be three places at once. I am right now chairing another meeting that is hopefully writing the definitive legislation to deal with the problem of acid rain, which I consider to be a very serious international problem. So I have a statement that I will have for the record and, with that, apologize to our distinguished panelists.

As we have already learned from Dr. Fuller's testimony, today's witnesses should help us answer two of the most delicate questions we have before us: How to balance the NSF budget between education and research, and how to balance spending among the research disciplines.

I am particularly concerned with the level of funding for education, as you are. All the research spending in the world won't mean much if this generation of researchers is our last. We have to make certain we are devoting enough attention and enough money to educating future generations.

There is evidence that we are falling short of the mark. Most American students take no science after the 10th grade, leaving them with far less grounding in science than their counterparts in West Germany and Japan, for example. At yesterday's hearing Dr. Hamburg of the American Association for the Advancement of Science pointed to the level of education funding as the one deficiency in NSF's proposed budget. He is not alone.

NSF could be doing more to improve precollege education and to bolster the community colleges and the liberal arts colleges that educate the bulk of our Nation's students. NSF has argued, in response, that the education programs need to be stable, but a program, like a patient, can be in critical but stable condition. I don't want to see stability if the program isn't yet healthy.

Of course, our research disciplines are not necessarily the picture of health either. Recent reports have pointed to the need for significant increases in such fields as chemistry and mathematics. I look forward to learning more about those reports today. As I have noted at each of our hearings, I am a strong supporter of the proposed increase for NSF, but we still must decide how best to put those dollars to use.

With that, and my apologies, I take leave to go try to solve another problem, but I want you to know that on both sides of this chair in the middle we are with you, and very supportive.

Thank you, Mr. Chairman.

Mr. WALGREN. Thank you, Mr. Boehlert. Thank you very much. Let's then turn to Dr. Paloumpis.

Dr. Paloumpis.

STATEMENT OF DR. ANDREAS A. PALOUMPIS, PRESIDENT, HILLSBOROUGH COMMUNITY COLLEGE, TAMPA, FL

Dr. PALOUMPIS. Thank you, Mr. Chairman.

I am very pleased to be here representing approximately 1,300 community and junior colleges throughout the United States. In the fall of 1986 the community colleges, the 2-year institutions, will register more than 50 percent of the freshmen that will be in attendance in college. I think that we are working with a very basic need: We are working with the education of students at the very, very early parts of their collegiate training.

Remember that the community college operates under an open door policy, where we are accepting large numbers of students who may not be acceptable at a university because of SAT scores, remedial needs, et cetera. But, I think, what is very, very important is to take a look at the product that we have produced at the end of the 2 years that they are with us. After 2 years, individuals who may not have been admitted to a senior institution have been successful in their work, transferred to a senior institution to finish their baccalaureate degree and are very successful in their endeavors at the senior institution.

I think that the thing that we have added into the educational system at the community college level is teaching, and teaching at its best. We have individuals who are not involved in research. We don't want them to be involved in research of that nature. We do want them to keep up to date, but the most important thing that we're dealing with is what happens in the classroom and what happens to the end product, the student that's coming out of our educational system.

We can refer to all of the statistics, where a student graduating from a community college can transfer to a senior institution, and we track them on their grade point average. If they are successful with us, they will continue to be successful in their endeavors.

In Florida, of course, I am very, very sorry that on one hand the State Legislature had to enter into the educational system and mandate that we would become accountable. On the other hand, I am very pleased that the Florida State Legislature was willing to take a very strong stand on the value of education, particularly science, mathematic education.

I am also very, very pleased that in doing this the Florida Legislature funded their programs that they told us that we had to address. As a result, it wasn't merely a matter of setting a philosophy that says, "We want better-trained individuals and better-educated individuals in science and mathematics," but we are willing to support the need for that kind of education.

I have been very, very pleased to see the kinds of things that we have been able to achieve, not only at our institution but also in many—and I would say the vast majority—of the community and junior colleges in the United States. In many cases we have done a great deal from the standpoint of retraining faculty, upgrading our faculty, which we know is our most important thing in this whole formula.

We have been upgrading our facilities, but we know we cannot do it alone. We have spent a considerable amount of our financial resources, over the past 2½ years that I have been in Tampa, in a new technology building, a $5.5 million first phase with an additional $4 million second phase coming off very quickly. We have already spent over $800,000 in equipping it with up-to-date or state-of-the-art equipment, and it has had its benefits.

Just recently we were recognized as a center of excellence in electronic technology by Governor Graham and the State of Florida. Our radiological technology program was also recognized as a top program in the State of Florida by the State Board of Education.

Those are things that we like to have. They are good for our ego but more importantly than that is the fact that we know that we are producing a product, that not only does our State need and our local community but also our Nation, and that is individuals who are well-educated and well-versed and well-grounded in the field of mathematics and science. All of these other things cannot fall into place unless we continue to build on this kind of a building block. This is a commitment that we have.

We have a very heterogeneous faculty. Some of our faculty are former high school faculty members. Some of them are individuals who have come to us from business and industry, where they were working on the line. Many others are faculty members who had been at a senior college, who were not interested in the research but were interested in the teaching.

We therefore have a very diverse background of faculty, and what we constantly need to do is to explore those ways in which we can help our faculty be even better teachers, and also keep them upgraded in their field that we have them working in. The problem that we are all facing is that the fields are changing so drastically and so rapidly that we don't even know what the new professions, the new fields are 10 years from now.

Thank God it is occurring that way, because that's what makes our job a very, very exciting one and a very important one. We have implemented a number of programs in which we are working with our faculty, with high school faculty in our county, and also with two colleges in our area—the University of Tampa and also the University of South Florida—in order that we can all get together to better prepare teachers, which in turn better prepares our students, so that we can continue to get the equipment and we can provide these programs that will produce these technicians and the transfer students who will then go on for the 4-year degrees and graduate degrees in science and technology.

We need the support for faculty training, for upgrading. We need the support to establish programs at upgrading. We need to continue to devote our energies to developing partnerships with business and industry. We have started this. We have been working very, very closely with one industrial park, business park, which donated 40 acres of land valued at over $3 million because they wanted a community college in the middle of an industrial business park, because they know the need for this kind of education. And we also need a support program for state-of-the-art equipment.

We urge you to support us in a commitment in the way that you can support us in our commitment. Thank you, Mr. Chairman.

[The prepared statement of Dr. Paloumpis follows:]

TESTIMONY

PRESENTED BY

DR. ANDREAS A. PALOUMPIS
PRESIDENT
HILLSBOROUGH COMMUNITY COLLEGE
TAMPA, FLORIDA

TO

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

FEBRUARY 26, 1986

I wish to thank you for the opportunity to address the subcommittee on a topic of vital importance to our nation. I am also honored that I have been requested to speak on behalf of our nation's community colleges.

As the President of Hillsborough Community College in Tampa, Florida, I have witnessed first hand the increasingly important role the College has played in developing partnerships with industry to meet the needs of new and advanced technology. It is vital that these partnerships be increased rather than remain static or decrease, if we are to meet the needs of business, industry, and our nation in the next century.

Hillsborough Community College currently enrolls approximately 14,000 students. We have three campuses, the Brandon Learning Center (eventually to become our fourth campus) and two environmental centers. The average age of our student body is approximately 29 years. We also offer numerous courses at off-campus sites, including MacDill Air Force Base and Sun City Center.

I have witnessed many changes in the support of mathematics and the sciences during the 36 years I have been associated with education. I have witnessed these changes as a high school science teacher in Mason City, Illinois, as a Professor of Zoology and Fisheries at Illinois State University in Normal, Illinois, as the Vice President for Academic Affairs at Illinois Central College in East Peoria, Illinois, as the President of Onondaga Community College in Syracuse, New York, and most recently as the President of Hillsborough Community College in Tampa, Florida. Although the level of support has fluctuated drastically during the past 36 years, whenever we have faced a crisis as a nation, we have responded to that crisis and have solved the problem.

There is no question in any of our minds that we are again facing a crisis in mathematics and science education. This time, though, the problem is more pervasive because we are not dealing only with the upgrading of baccalaureate and graduate education, but also with the need to educate highly skilled technicians at the Associate degree level.

I do not wish to belabor the distinguished members of the subcommittee with facts and figures which you have already received, but it is necessary to highlight some of the more important statistics:

1. International comparisons of student achievement completed a decade ago, reveal that on 19 academic tests, American students were never first or second and, in comparison with other industrial nations, were last seven times.
2. Average achievement of high school students on most standardized tests is now lower than when the Russians launched Sputnik.
3. The College Board's Scholastic Aptitude Tests (SAT) demonstrate a virtually unbroken decline from 1963 to 1980. Mean verbal scores have dropped over 50 points and mean mathematics scores have dropped nearly 40 points.
4. Over half of the population of gifted students do not match their tested ability with comparable achievement in school.
5. Average tested achievement of students graduating from college is lower today than it was ten years ago.
6. Business and military leaders complain that they are required to spend millions of dollars on costly remedial education and training programs in the basic skills area.

We are a nation at risk. Educators have yielded to fads and external pressures. We have been guilty of touting the "new math" fad because it supposedly made learning easier. We have been guilty of yielding to specialized group pressures to allow the students to develop their own curricula and to do their own thing. We have been guilty of yielding to parental pressures and legislative pressures.

Educators have traditionally been reluctant to critically examine themselves and the product they are producing. It is a sad commentary that the Florida Legislature had to enter the picture and demand accountability from all educational institutions in the state. I am pleased, though, that our State Legislature has been willing to address a problem of this magnitude rather than avoiding the issue. The Florida State Legislature has taken the initiative with the adoption and funding of the following legislation:

1. The College Level Academic Skills Testing (CLAST) tests basic reading, writing and computation skills before a student is permitted to proceed to the junior year in college. Passing the CLAST is required of all sophomores in both the community colleges and the senior institutions.
2. The Gordon Rule requires all students must have six semester hours of mathematics at the college algebra level or higher. The Gordon Rule also requires mandated writing for all students.
3. The RAISE Bill requires all high school students graduating in 1987 to have three years of mathematics, three years of science, two years of foreign language, and a half-year of computer literacy.
4. The Omnibus Education Bill mandated college placement examinations in reading, writing and mathematics. The bill also designated the community colleges as the centers for college preparatory programs in the basic skills.

Hillsborough Community College has responded to this crisis that we currently face. Although I will address the accomplishments of the institution with which I am associated, it is imperative to state that Hillsborough Community College is not unique in addressing the problem. Almost all of the 1300 community and junior colleges in the United States have placed a high priority on this problem and are addressing it using a variety of approaches.

We responded to the commitment for excellence in the following manner:

1. Algebra is a prerequisite for all college legal mathematics courses.
2. The general education science requirements were increased from six semester hours non-laboratory to eight semester hours with a required laboratory

experience. We are the only community college in the state that requires every science course to have a laboratory experience.

3. Renovated and equipped laboratories at the Ybor City Campus.
4. Provided 70 microcomputers at our four instructional locations.
5. Added formal laboratory courses to the curriculum supporting college preparatory mathematics.
6. Implemented state-mandated placement examinations.

It has been difficult for our educational institutions to keep pace with the technological advances and the change in the way we do business. Employment opportunities have changed dramatically during the past few years. Traditional employment opportunities are disappearing while the opportunities for technicians and service related jobs are rapidly increasing.

In addition to upgrading our basic educational offerings to properly educate our students, Hillsborough Community College has made a strong commitment in providing up-to-date facilities and equipment supporting our numerous technology programs.

1. Established an academic/instructional computer network on all campuses linking the various labs using computers for instruction.
2. Completed the first phase ($5.5 million) of a $9 million technology building.
3. Have expended approximately $800,000 to equip our new facility with state-of-the-art equipment.

We have dedicated a considerable portion of our financial resources to the upgrading of physical plant facilities and equipment to be utilized in instruction. While it is painfully obvious that we do not possess the financial resources to adequately upgrade all of our facilities, it is gratifying to note that our efforts in specialized areas of instruction do not go unrewarded. Our electronics training program has just been designated as a Center of Excellence, and our Radiological Technology Program has been approved as an outstanding program by the Florida State Board of Community Colleges. We will continue with our long-range plan to provide proper facilities and equipment so vital to the education of our students.

We also work very closely with representatives from business and industry in updating our numerous curricula to ensure that our graduates are well prepared for entry into employment. We are currently providing courses in-plant upgrading the current employees of several industries.

This joint cooperative atmosphere between Hillsborough Community College and the business community resulted recently in a gift of 40-acres of land in Sabal Park by Stone and Webster, Inc. to serve as the permanent location of our Brandon Learning Center. This land, valued in excess of $3 million, is located in a business park currently housing 40 companies in 2 million square feet of space and employing 2,000 individuals. At final build-out, the park will contain 6 million square feet of space and employ in excess of 14,000 individuals. Hillsborough Community College will be playing an important role in providing highly skilled employees for the varied businesses in the park as well as providing training and upgrading for the current employees. The updated curricula, new and renovated physical facilities and new equipment are worthless unless qualified faculty exist to instruct these programs. All institutions are competing to attract the recent graduate qualified to teach in these important areas. The problem is further compounded by the fact that many of our currently employed faculty members must be retrained to meet our newly updated standards and our new programmatic thrusts or face the stark reality of unemployment. Shifts in student enrollments have resulted in reduced teaching loads for some faculty members.

The faculty members in the community colleges possess very heterogeneous backgrounds: former high school teachers, former industry employees and former senior college faculty with research-oriented degrees. We are addressing the problem of faculty development in a variety of ways.

1. Last summer our Board of Trustees approved our recommendation defining the minimum standards for a faculty member to be employed in a given discipline.
2. We are providing formal courses to additionally train existing faculty members to teach college preparatory mathematics funded under Title II - Education for Economic Security.
3. A jointly funded program with the University of Tampa for retraining Hillsborough Community College faculty and secondary school teachers for computer learning. This project was also funded under Title II - Education for Economic Security.

It is imperative to remember that in excess of 50 percent of the 1986 college freshman class will be enrolled in our nation's community colleges. The graduates from community colleges are highly successful when they transfer to the senior institution to complete their four-year degree. The transfer success statistics speak directly to the quality of education received in the community college. The employment rate and success of graduates from our technology programs also speaks directly to the quality of instruction.

We have made a firm commitment to reestablish and maintain the characteristics leading to Excellence in Education. We desperately need your support and assistance in the retraining of faculty and the upgrading of equipment which will continue the improvement in the quality of science and mathematics education in the two-year college.

We strongly suggest that funding for science and mathematics should not be concentrated through the National Science Foundation only for the support of research and graduate education. We recommend the following for your consideration:

1. Support funding for the Walgren Community College Bill.
2. Establish a program aimed at upgrading community college faculty in the sciences and technologies.
3. Support a program that will assist the community colleges in continuing to develop partnerships with business and industry.
4. Support a program that will assist the community colleges in acquiring state-of-the-art equipment.

The nation's community and junior colleges have demonstrated their commitment to excellence in serving the complex needs of our society. We ask that you support us in this commitment.

Mr. **Walgren**. Thank you very much, Doctor. We appreciate that.

Now we will turn to Mr. Bloom. Welcome to the committee.

STATEMENT OF JOEL BLOOM, DIRECTOR, BENJAMIN FRANKLIN INSTITUTE, PHILADELPHIA, PA

Mr. **Bloom**. My name is Joel Bloom. I am president of The Franklin Institute Science Museum in Philadelphia. It's the science museum at the other end of the State, Mr. Walgren. And I am immediate past president of the Association of Science Technology Centers, a nationwide organization of almost 200 science technology museums.

I would like to speak to you today about the defense budget of the United States—yes, the defense budget, not the fiscal 1987 defense budget but the defense budget of the year 2000—the year 2000, when today's fourth grader will be a technologically illiterate young adult in America unable to meet the scientific and technological demands of economic and national security.

Which brings me right back again to the NSF budget for fiscal 1987. The 1987 NSF budget calls for an overall increase of some 8.4 percent over the program level for fiscal 1986. The science and engineering education activities are budgeted at $89 million, a teeny 5.3 percent of the total NSF budget. Within science and engineering education, the college science instrumentation subactivity is budgeted for a very much needed $2 million increase. Other vital activities—materials development, research, informal science education, teacher preparation and enhancement—are budgeted at their fiscal year 1986 level to help stabilize them. Unfortunately, the problem hasn't stabilized.

A great deal has been written about the crisis in science education. In fact, Mr. Boehlert said it all for me a few moments ago. I would like to bring it home to us. Subcommittee chairman Walgren, Congressman Ritter, and I are Pennsylvanians, and in Pennsylvania, the home of America's first scientist, last year only eight new teachers were certified to teach high school physics, and none of them went into teaching—none of them.

Sometimes I find it hard to meet the eyes of the great James Earle Fraser statue of Benjamin Franklin in the Benjamin Franklin National Memorial in my museum, knowing how distressed Franklin would be at this grave threat to his country's future.

I would like to speak to you a bit today about one of the important elements in the nationwide collaborative effort to improve science education—science museums or science technology centers, as they are called. Better still, I wish you could visit a science museum in Columbus, in Dallas, in Boston, in Charlotte, in Philadelphia, in Harrisburg, in Bloomfield Hills, in Baltimore or Seattle this Saturday night—yes, Saturday night. You could watch busloads of Girl Scouts and Boy Scouts arriving at any one of these museums for an overnight program called Camp-In.

Visit any of the growing number of Camp-In sites, and you will enjoy watching young people respond enthusiastically to the excitement of science learning. You will see them participating in hands-on experiences, live demonstrations, workshops, exhibits, planetarium shows, opportunities to explore, to touch and to be touched by science. In fact, our biggest problem is getting the youngsters to go to sleep. At The Franklin Institute we hit upon the notion of a disco in the Benjamin Franklin National Memorial. We let them dance themselves into sleepy exhaustion under Franklin's very approving gaze.

I would like to read you some excerpts from a letter a Girl Scout leader wrote to the person in charge of our Camp-In Program:

> Dear Carol: I just wanted to let you know what a terrific experience my troop and I had Friday night at the "Camp-In."
>
> My daughter was having a bowl of soup before taking her nap, and looked at her upside-down reflection in the spoon and said, "I always wondered why my reflection was upside down, and now I know that it's because it's concave."
>
> Thanks for a wonderful time. We'll be little old ladies and still talk about "the night we slept in at The Franklin Institute."

Science museums are a unique arena for science learning. In their informal, self-paced setting, people encounter basic science principles; they touch old objects and new objects; they see rare historical artifacts; and they have the freedom to explore and discover the physical world. It is a nonthreatening place for people to learn from permanent exhibits, traveling exhibits, and programs.

Speaking of traveling exhibits, I picked up this device from our carpentry shop this morning on the way to the hearing. It's a set of blocks of wood with a piece of rubber shock cord holding them together. I can tighten up the shock cord and experiment with how hard it is to deform the blocks. It lets the visitor experiment with two basic concepts of structures—tension and compression. With it, literally one can feel why they put iron bars wired into place before they pour concrete on a construction site.

This device is part of an NSF-supported exhibit on structures which will be on display—I should say "in use"—here in the Capital during National Science Week before its tour to science museums around the country under the auspices of the Association of Science Technology Centers. We look forward to a very exciting stay in Washington, and we are particularly grateful to Congressmen Fuqua, Walgren, Boehlert, and Lujan for their sponsorship of the National Science Week resolution. It should do much to draw the Nation's attention to both the promises of science and technology and some of the problems we face. Please come and bring your families to the congressional reception, which is going to take place between 5 and 7 on May 13. There will be a staff breakfast the same day.

During the past few years, many science museums have adapted their skills and experiences to enter a new area of science education. These museums are providing special programs that directly affect classroom teaching. I'll talk about those at my own museum because I know more about them, but they are typical of what is happening everywhere in the United States.

As you know, the problem of school science teaching is serious at every level. It is particularly acute at the elementary level, when children are forming their basic attitudes toward science. In Philadelphia we have begun a multifaceted cooperative attack on the problem. It's called Philadelphia renaissance in science and mathematics—as an acronym, of course, called PRISM. PRISM enjoys the support of the school districts, the business community, and the museums and universities.

We are very active in PRISM. Our major activity, which began with the support of the Atlantic Richfield Foundation—and most of these things are cooperative ventures between industry, school districts, the Federal Government, and museums—we call our project Museum-to-Go, and that's what it is—an opportunity for elementary school students to experience the science museum in their own classrooms.

Museum-to-Go is a comprehensive program designed to provide training and materials in experiential science education techniques to elementary and middle school teachers. Developed with and for teachers, its activities are divided into two mutually reinforcing areas—development, production, and distribution of interactive science education kits for use by teachers and students; and development and presentation of workshops to train the teachers in the hands-on science education.

Museum-to-Go provides teachers with resource materials and proven techniques for conducting exciting curriculum-related student activities. It trains teachers in using these activities and in manipulative instructional materials that are often not available in their schools.

Thanks to the unstinting cooperation of Philadelphia school district administrators and teachers, Museum-to-Go has surpassed our wildest expectations. For example, there is a school in North Philadelphia called the Moffett School. The children come from 26 different nationalities. Fewer than 10 percent are native English-speaking. Although many are hardly able to speak English, all were able to participate in science because their teachers at the fifth and sixth grade level took our workshops and used our hands-on activities.

As part of an English language exercise, the children wrote to our teacher and invited her to spend a Thanksgiving party with them. She took them up on the invitation, and two Asian children, speaking broken English, gave her a tour of their classroom. They pointed out the experimental setups and proudly explained parallel and series circuits. She pretended not to understand and asked if the wires in their homes were in parallel or series. They giggled and explained that at home the circuits were parallel, of course, for if they were in series and one bulb burned out, all the lights would go out.

But why hear about hands-on experiences when you can do them yourself. This is part of a kit on heat. Children put this kit together. All the parts are furnished by the teacher. It has a bimetallic strip on the top and a weight, a candle. We furnish everything. We don't make the teacher scrounge for things. It transfers stored chemical energy to heat energy, and heat energy to mechanical energy. It is from things like this that children really learn effectively.

I hope I have given you some idea of what science museums can do and are doing to address the crisis in science education, both as freestanding institutions and in collaboration with local school systems, especially teacher training. I started with some comments about the NSF budget, and I would like to go back to it.

From its virtual elimination in the early 1980's, the NSF Science Education Program has staged an impressive comeback. Dr. Bassam Shakhashiri, head of science and engineering education, is himself an impressive science educator. He has built a first-rate team including, for the first time in my memory, an elementary and a high school science teacher. Dr. Shakhashiri is wise enough to go to the real experts—the teachers themselves.

Two years ago the Division of Informal Science Education was established. It has provided a total of 13 grants to museums—3 of them to consortia. We think it has the potential to reach between 100 and 200 museums over the next few years. Typical grants are described in my written testimony.

It's a good beginning, but I think all of us in science education share a well-founded anxiety. NSF Director Erich Bloch has proposed an 8.4-percent overall funding increase, primarily for much-needed investment in civilian basic science and engineering research. This modest increase is certainly a wise investment in America's future. To help stabilize science and engineering education, no increases have been requested in the equally vital area of science education, with the single exception of science instrumentation.

And what is going to happen when the inevitable budget-cutting takes place, be it Gramm-Rudman or some other initiative? The rest of the Foundation may well be cut back to the 1986 level, and science and engineering education will be cannibalized once again. Science education is written into NSF's statutory charter as a primary responsibility. Indeed, as you well know, it was once 44 percent of the NSF budget. It is now only 5.3 percent. The crisis grows, and the percentage allocated to solving it shrinks.

Even if we were to go back to those budget levels, NSF would be unable to solve the problem entirely. It is simply too big. What is required is a nationwide coalition of local school districts, industry, museums, universities, television, and community groups, with the Federal Government through NSF acting as a leader and a catalyst. It's a national problem and we must address it at a national level.

But is it leading, when NSF treats science education as a poor stepdaughter and singles it out for stabilization amidst overall growth? The tools are available; the need has never been greater. How long can we as a nation continue to eat our seed corn? Will we have anything to harvest by the year 2000? Our children—and, I daresay, Benjamin Franklin himself—will never forgive us, nor should they, if we continue along this self-destructive path.

Again, thank you for the privilege of appearing before this subcommittee.

[The prepared statement of Mr. Bloom follows:]

TESTIMONY OF

JOEL N. BLOOM

PRESIDENT
FRANKLIN INSTITUTE SCIENCE MUSEUM
PHILADELPHIA, PENNSYLVANIA

IMMEDIATE PAST PRESIDENT
ASSOCIATION OF SCIENCE-TECHNOLOGY CENTERS

SCIENCE, RESEARCH, AND TECHNOLOGY SUBCOMMITTEE
COMMITTEE ON SCIENCE & TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

February 26, 1986

Dear Mrs. Iris-Williams

Thank you for the batteries, bulbs, and wires that you gave to us. We like to make electricity. It is interesting and exciting. Your friend,

Poliana González.

We are using the batteries and bulbs you gave us and getting smarter because of them. I told my Mother that I was happy and science was my best subject. I am learning how to connect wires and lots of important things.

Your friend,

Damian Toro

Quite recently, one of the science teachers praised my ability to involve and sustain the interest of my physical science students. She had observed my students working on a hands-on activity from one of the ARCO Program Kits. I couldn't take full credit for the compliment, and thought that this would be an appropriate time to express my appreciation to the Franklin Institute Science Museum "Museum-To-Go-Resource Center."

We are aware of the need to educate our students at an earlier age in the fundamentals of science. This lack of preparation is a major problem facing the junior high science classes.

Sincerely,

Barbara Bess
Physical Science Teacher

Will you please send us some more things that will help us learn Science. We are happy about all the things you give us.

Your friend.
Erni Linda Gonzalez

I can't wait until my teacher brings us magnets so I can see what we are going to do with them. Love,

Maria Diaz

My name is Joel N. Bloom. I am President of The Franklin Institute Science Museum in Philadelphia, and immediate past President of the Association of Science-Technology Centers -- a nationwide organization of almost 200 science and technology museums. The Institute has been engaged in science education and encouraging public understanding of science and technology since 1824. I greatly appreciate the opportunity to testify before you today.

I am here to talk about the United States defense budget. Yes, the defense budget. Not the fiscal year 1987 defense budget, but the defense budget of the year 2000. The year 2000 when today's fourth grader will be a technologically illiterate young adult in an America unable to meet the scientific and technological demands of economic and national security - which brings me to the National Science Foundation (NSF) budget for fiscal year 1987. The 1987 budget for NSF calls for an overall increase of some 8.4% over the program level for fiscal year 1986. The Science and Engineering Education (SEE) activities are budgeted at $89 million, a tiny 5.3% of the total NSF budget and actually less than the overall $130 million increase. Within Science and Engineering Education, the college science instrumentation subactivity is budgeted for a $2 million increase. Other vital activities such as materials development, research and informal science education, and teacher preparation and enhancement are budgeted at their fiscal year 1986 level "to help stabilize" them. Unfortunately, the problem has not stabilized.

We face a national crisis in science education in our schools. There is no doubt about it. Numerous recent studies have documented the poor quality of science education in our schools, and strongly suggest that our country is facing an epidemic of science illiteracy -- an epidemic far more widespread and more dangerous than the polio epidemic of my youth. But it's hard to come to grips with national epidemiology. Subcommittee Chairman Walgren, Congressman Ritter, and I are Pennsylvanians, and in Pennsylvania, the home of America's first scientist, last year, only eight new teachers were certified to teach high school physics, and none of them went into teaching. Not one.

Sometimes I find it hard to meet the eyes of the great James Earle Fraser statue of Benjamin Franklin in the Benjamin Franklin Memorial in my own museum, knowing how distressed Franklin would be at this grave threat to his country's future.

Put simply, the nation that boldly led the world into the space age of the 1960's and the information age of the 1980's is failing to prepare its citizens with the tools needed for the next century. The next century -- it sounds comfortably far away; it isn't. It is right around the corner. The solutions to the crisis in science education are complex and expensive, but the alternative is terrifying and far more costly. It will take the collaborative efforts of industry, educators, museums, government, students and parents, and an unprecedented pooling of resources to overcome the grave obstacles ahead. Yet the National Science Foundation proposes "to stabilize" science education support. Is this the message the Congress wants to send to the American people? I hope not.

I would like to speak to you today about one important element in the nationwide collaborative effort to improve science education - science museums or science technology centers as they are often called.

Better still, I wish you could visit a science museum in Columbus, Dallas, Boston, Charlotte, Philadelphia, Harrisburg, Bloomfield Hills, Baltimore, or Seattle this Saturday night. You could watch bus loads of Girl Scouts and Campfire Girls arrive at any of these museums, some of them having ridden for as long as 7 hours, for an overnight program called "Camp-In." Visit any of the growing number of Camp-In sites and you'll enjoy watching young people respond enthusiastically to the excitement of science learning. Camp-Ins were developed by the Center of Science and Industry in Columbus, Ohio, some fourteen years ago, and as is common in the science museum world they have generously shared their experience and know-how. The Camp-Ins offer hands-on experiences in science, live demonstrations, workshops, exhibits, planetarium shows, opportunities to explore, to touch, and be touched by science. Indeed our biggest problem is getting the youngsters to sleep. At The Franklin Institute we hit upon the notion of a disco in the Benjamin Franklin National Memorial where they dance themselves into sleepy exhaustion under Franklin's approving gaze. May I share a letter from a mother/scout leader to our Camp-In Director.

> Dear Carol:
>
> I just wanted to let you know what a terrific experience my troop and I had Friday night at the Camp In. We appreciate all your hard work and effort in putting such a fun project together. Every girl who went with me was happy -- and very tired -- and the parents were pleased with the projects brought home.
>
> My daughter was having a bowl of soup before taking her nap, and looked at her upside-down reflection in the spoon, and said "I always wondered why my reflection was upside down, and know that it's because it's concave." That's one workshop she paid attention to. Another girl commented when her brother put the airplane together incorrectly and it wouldn't fly, "It's because of the lift and thrust."
>
> Thanks for a wonderful time, and we'll be little old ladies and still talk about "the night we slept at the Franklin."
>
> Very truly yours,
>
> Charlene Carney, Tired Leader

Since the founding of the nation's first modern science technology museums in Chicago and Philadelphia some fifty years ago, these very special museums have played an important role in public understanding of science and technology, and in science education. Today, across the nation, science and technology centers are arousing public interest in science and are providing a growing range of educational activities. Hands-on exhibits (where people can actually experiment with science principles themselves), stimulating programs and workshops, and special outreach to minorities and women are just some of the reasons that more people visit science museums each year than attend all of the professional baseball, football, and basketball games combined.

Science museums are a unique arena for science learning. In an informal, self-paced setting, people encounter basic science principles; they touch old objects and new; they see rare historical artifacts, and they have the freedom to explore and discover the physical world.

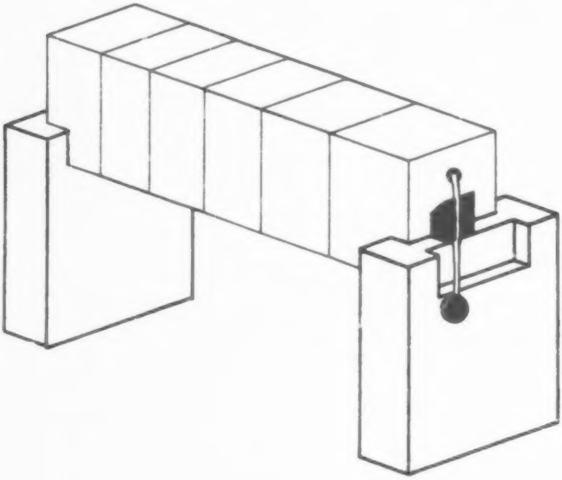
Museums are a neutral place -- away from schools and colleges, away from the politics and complexities of big city educational systems. They are independent places where teaching methods and exhibits are not merely theoretical but tried and tested by hundreds of thousands of people each year. Museums provide a non-threatening place for people to learn from permanent exhibits, traveling exhibits, and programs. Speaking of traveling exhibits, I picked up this device from our carpentry shop this morning. (Mr. Bloom demonstrates device shown in Figure 1.) The rubber shock cord threaded through the blocks can be tightened or loosened. It lets the visitor experiment with two basic concepts of structures -- tension and compression. With it, one can literally feel why a network of iron bars is carefully wired in place before concrete is poured in a building under construction.

The device is part of a NSF-supported exhibit on structures which will be on display -- I should say in use -- in the Capital during National Science Week before its tour to science museums around the country under the auspices of the ASTC Traveling Exhibit Service. We look forward to an exciting stay in Washington and are particularly grateful to Congressmen Fuqua and Walgren for their sponsorship of the National Science Week resolution. It should do much to draw the Nation's attention to both the promise of science and technology and to our grave problems in science education.

During the past few years, many science museums have adapted their skills and experiences to enter a new arena of science education. In addition to proven public programs and exhibits, these museums are providing special programs that directly affect the classroom teaching of science. I'll talk about those at my own museum because I know more about them, but they are typical of what is happening everywhere as more and more school districts turn to the museum community for collaborative efforts in science education and teacher training.

While the problem of school science teaching is serious at every level of the educational system, it is especially acute at the elementary level at the time when children are forming their basic attitudes towards science. Recent studies have shown that elementary school teachers place a low priority on the teaching of science. Surveys of student attitudes indicate that they acquire a dislike of science early in elementary school. By the end of the third grade,

Pre-stressed Beam



Carefully loosen the elastic cord, then push down on this beam. It is not very strong. Pull the elastic cord tight and clamp it. Now push on the beam. Is it stronger?

nearly half the students say they do not want to take science. By the time they reach the eighth grade, only 21% have a positive attitude toward science courses. This means that 80% -- well over 3/4 -- are negative about this crucial subject.

Regrettably, many teachers do not use the techniques that can develop children's capacities for scientific problem-solving and critical thinking. They do not use experiential learning to nurture children's natural curiosity and instill an awareness of the science relevant to their everyday lives. The science program in most elementary schools is limited to reading from a textbook, the memorization of "scientific" vocabulary words, and the regurgitation of this information in class recitation and on tests. As a result, many children are left with the impression that science is boring, incomprehensible, and irrelevant, at the time when they are forming attitudes that will affect the extent of their future education in science and their choice of a career. Perhaps because neither teachers nor students enjoy science as it is taught in most elementary schools, the teaching of science is virtually disappearing from elementary school classrooms.

In Philadelphia we have begun a multi-faceted approach to the problem. School Superintendent, Dr. Constance Clayton, and her able administrative staff are strongly committed to improving science education; teachers and their union leadership are willing and eager to implement improvements in the classroom. A new standardized curriculum has been adopted in an effort to assist teachers, improve the quality of education, and assure higher student achievement.

In addition, the Philadelphia School District and the Committee to Support Philadelphia Public School (CSPPS) are mounting a major science/mathematics initiative, Philadelphia Renaissance in Science and Mathematics (PRISM). PRISM is chaired by Mr. Theodore Burtis, Chief Executive Officer of the Sun Company. CSPPS is a partnership of business, foundations, cultural and higher education institutions, and the public schools of Philadelphia. It enjoys the personal support and encouragement of the leading corporate executives in the Philadelphia area. Its broad goal is to strengthen science education by developing an extensive mathematics and science initiative and expanding connections between the school district, museums and other educational institutions and the private sector. A particular concern is to increase the enrollment and achievement of minority students in higher level mathematics and science courses.

The Franklin Institute is active in PRISM, but our major activity, begun with the initial support of the Atlantic Richfield Foundation and later by the Guilliam H. Clamer Foundation and the Committee to Support the Philadelphia Public Schools, has been the development of a project we call Museum-To-Go. That is precisely what it is -- an opportunity for elementary school students to experience the science museum in their own classrooms. Museum-To-Go is a comprehensive program designed to provide training and materials in experiential science education techniques to elementary and middle school teachers. Developed with and for teachers, its activities are divided into two mutually reinforcing areas: 1) development, production, and distribution of interactive science education kits for use by teachers and students and 2) development and presentation of workshops to train teachers in hands-on science education. Museum-to-Go provides teachers with resource materials and proven techniques for conducting exciting curriculum-related student activities. It trains teachers in using these activities and in manipulative instructional materials that often are not available in their schools. Area teachers, supervisors and administrators are involved in every aspect of the kit development. The kits are designed to be easy to use in the classroom.

Each kit focuses on a limited number of activities and can "stand alone" as a curricular resource. This allows an experientally-based program to be presented to teachers in manageable segments. Classroom implementation is immediate as a teacher attends the appropriate workshop and receives an accompanying kit. Teachers need not commit immediately to an entire year of hands-on science, but can proceed step-by-step into a program as training improves their skills, confidence, and level of readiness.

The kits correlate with the standard elementary school science curriculum and emphasize the physical and earth sciences, areas in which teachers feel particularly insecure. They welcome the opportunity to address what they feel are their own inadequacies. Indeed, our workshops are always oversubscribed. We have barely begun to meet this need.

Each kit is a self-contained resource package, with all the materials required for an entire class to conduct simultaneously a manageable number of key experiments on a given topic. This means that teachers need not spend valuable time seeking and organizing these materials. Also, these are loan kits. Materials can be replaced after each use so that the next teacher receives a classroom-ready package. Each kit includes student activity sheets which describe the experiments, provide for recording data, and make suggestions for further inquiry as well as a teacher's guide.

The kits are only available to teachers if they attend training workshops. The workshops serve to train classroom teachers and elementary specialists in effective use of experiential science materials, serving to enhance basic science knowledge as well as teaching techniques.

We have learned that the principal concern of elementary teachers with science materials is how to use them. Each teachers' workshop covers a different topic and focuses on four interrelated dimensions:

-- How to Teach Science -- Methods for effective teaching of experiential science with focus on the accompanying loan activity kits.

-- What to Teach -- Science concepts and processes based on standard curriculum topics to reinforce teachers' understanding of the content.

-- Why Teach Science? -- Philosophical basis, research findings, and real-life relevance so that teachers understand the importance of teaching science.
-- How to Evaluate Learning -- Suggestions on what criteria and measures to employ in determining what students are learning.

Typical units include:

-- Chemistry: Acids, Bases & Salts -- Introduces the chemistry of acids, bases and indicators as a means to examine some of the properties of common household items.
-- Energy -- Using familiar materials and easily constructed devices, this unit approaches the topic of energy conversion by concentrating on stored or potential energy and its release as kinetic energy or work.
-- Measuring Forces -- Approaching the study of force through a variety of hands-on observations and activities, this series also promotes the development of accurate measuring skills and an understanding of the measurement process integral to most scientific endeavors.

Thanks to the unstinting cooperation of Philadelphia School District administrators and teachers, Museum-To-Go has surpassed our wildest expectations. For example, the Moffett School in North Philadelphia has children of twenty-six nationalities. Fewer than 10% are native English-speaking. Although many were hardly able to speak English, all were able to participate in science because their teachers at the fifth and sixth grade level took our workshops and used our hands-on activities. As part of an English language exercise, the children wrote to our Museum-To-Go instructor.

"Dear Mrs. Iris-Williams:

Thanks for sending us the box of batteries, bulbs, and wire. We all use them in Science Class. I liked the experiment where we took a bulb, a battery and two wires and found out what things would conduct electricity. On November 26, 1985, we are cooking a Thanksgiving dinner. It is also Mrs. Bradley, our teacher's birthday. You are invited. I hope you keep sending us more batteries and bulbs. We are learning a lot.

Your friend,
Yasmin Santana

Mrs. Iris-Williams took them up on the invitation. Two Asian children, speaking broken English, gave her a tour of their classroom, pointing out the experimental setups and proudly explaining parallel and series circuits. She pretended not to understand and asked if the wiring in their homes was parallel or series. They laughed and explained that at home the circuits were parallel, of course, for if they were in series and one bulb burned out, all the lights would go out. Not bad, for eleven and twelve year-olds. They're excited about learning science now, and asking for more.

But why hear about hands-on experiences when you can do them yourself? (Mr. Bloom demonstrates device shown in Figure 2.) This is part of a kit on heat. It shows how stored chemical energy can be transformed to heat energy and how the heat energy can then be transformed into mechanical energy.

I hope I have given you some idea of what science museums can do and are doing to address the crisis in science education, both as free-standing institutions and in collaboration with local school systems, especially in teacher training.

I started with some comments about the National Science Foundation Science and Engineering Education budgets and programs, and would like to return to that subject. From its virtual elimination in the early 80's, the NSF's science education program has staged an impressive comeback. Dr. Bassam Shakhashiri, head of Science & Engineering Education (SEE), is himself an impressive science educator. He has built a first-rate team including, for the first time in my memory, an elementary and a high-school science teacher. Dr. Shakhashiri is wise enough to go to the real experts--the teachers themselves. From a low of 39 staffers, it's up to its full complement of 65. An impressive, broadly representative advisory board serves it well. NSF Director, Erich Bloch, is to be commended on a fine beginning.

Two years ago, the Division of Informal Science Education was established. ISE has provided a total of 12 grants to museums (3 to consortia) with the potential to reach between 100-200 museums over the next few years. Twelve other recent grants went to media projects.

Typical projects include a grant to the Milwaukee Public Museum to build an 11,000 sq. ft., 30-unit permanent exhibit about the South American tropical rain forest which provides much of the oxygen we all breathe - the only permanent exhibition that ISE has funded to date. It is expected to reach 500,000 people annually. The exhibit developers have worked closely with the Milwaukee Public School System, which has resulted in the incorporation of this exhibit into the seventh-grade curriculum.

The Boston Children's Museum received $366,406 in 1984 to develop interactive exhibits on ancient and modern technologies. A series of six hands-on exhibits, which compare ancient and modern technologies were developed to contribute to science awareness of young children, their parents, and their teachers.

The Exploratorium in San Francisco received $437,300 to develop a series of exhibits concerning cellular and molecular biology. A total of 35 interactive exhibits using living animals and plants will focus on biochemistry and biophysics of cells and will include displays on osmotic pressure, oscillation, and feedback and control.

1 How does heat affect a bimetallic strip

Heat

Materials

For each group
- bimetallic strip
- wooden stand
- tape
- candle & matches
- paper clip
- weight

Set up and conduct your activity

Part I

1) Tape the end of the bimetallic strip without the hole on top of the wooden stand

2) Hold a lighted candle under the free end of the strip and observe

3) Remove the candle and observe the strip as it cools

4) Turn the strip over and repeat steps 1-3. Record your observations

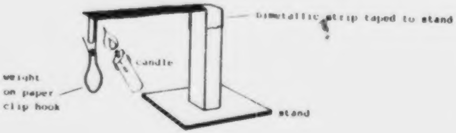
Part II

1) Tape the strip so the printed side faces up

2) Hang the weight by a paper clip attached to the hole in the bimetallic strip. Observe what happens to the strip

3) Hold a lighted candle under the strip and observe

4) If time permits, repeat adding a second weight



Record your results

Part I	Does the strip move?	Direction of movement
Printed side up		
Printed side down		

Part II

Observations:

Summary question

What do you think causes the bimetallic strip to bend when heated?

Other ideas to explore

How does a thermostat use a bimetallic strip?

Can you design a simple device that uses this principle to lift something?

Try the activity with various metal strips such as a strip cut from an aluminum pie plate

Can you make your own bimetallic strip?

Several non-museum projects have also been funded during the past several years. A four-year grant of $7,455,000 to the Children's Television Workshop in New York for planning, development, and production of the award-winning daily children's science television series, "3-2-1 Contact"; and a three-year grant of $8 million to develop a children's television series about mathematics. 98% of the households in the U.S. have television sets -- these programs could reach virtually every child in the country, for pennies per child.

It's a good beginning, but we all share what I feel are well-founded anxieties. NSF Director Erich Bloch has proposed an 8.4% overall funding increase -- primarily support for much-needed "investment in civilian basic science and engineering research." This modest increase is certainly a wise investment in America's future. To "help stabilize" SEE, no increases have been requested in the equally vital area of science education with the single exception of college science instrumentation.

We live in an era of reduced expectation, and NSF is only trying to do its share. Regrettably, it's doing more than its share in science education.

When the inevitable budget cutting takes place--be it Gramm-Rudman or some other initiative--the rest of the Foundation may well be cut to 1986 levels, and SEE will be cannibalized once again. Science Education is written into NSF's statutory charter as a central responsibility. Indeed, as you well know, it was once 44% of the NSF budget. It's now only 5.3%. The crisis grows, and the percentage allocated to solving it shrinks. Even if we were to go back to those budget levels, NSF would be unable to solve the entire problem. It's simply too big.

What is required is a nationwide coalition of local school districts, industry, museums, television, and community groups, with the federal government, through NSF, acting as the leader and catalyst. It's a national problem, and we must addresss it on a national level.

But is it leading, when NSF itself treats science education as a poor stepdaughter, singled out for "stabilization" amidst overall growth? The tools are available and the need has never been greater. How long can we continue to eat our seed corn? Will we have anything to harvest by the year 2000?

Our children--and, I dare say, Benjamin Franklin himself--will never forgive us. Nor should they, if we continue along this self-destructive path.

Again, thank you for the privilege of appearing before the Science, Research, and Technology Subcommittee.

Mr. **Walgren**. Well, thank you very much for that testimony and for this, too, especially. I will appreciate it more than most, because you would be amazed what the average home doesn't have that these kinds of experiments in Mr. Wizard's books or others call for. [Laughter.]

Mr. **Bloom**. If I may comment, Mr. Walgren, one of the things we have found in these kits for teachers, everybody tells the teacher, "Why don't you scrounge 75 rubberbands, 84 paper clips, 28 candles?" What teacher is going to do that? We put all the things in a box and give it to them.

Mr. **Walgren**. Yes, yes. We didn't have wax paper the other day. [Laughter.]

And, thinking about it, I think wax paper went out about 10 years ago, but in any event we didn't have any and that was a problem. Well, I'll look forward to this. We'll have a lot of fun with it.

Mr. **Bloom**. Great.

Mr. **Walgren**. I'm interested in your saying, Mr. Bloom, that the NSF budget was 40 percent science education in some period of time. I wonder what happened between then and now?

Mr. **Bloom**. In 1952 it was 44.4 percent, and it was 46 percent in 1959, and then it started dropping, dropping, dropping. As you know, in the eighties it dropped to nothing, and now it has been reconstituted, but still, 5 percent of the total NSF budget is a joke, considering the need.

Mr. **Walgren**. Yes, yes. You know, if we could get that information to the President, his big deal is that in the 1950's defense was 60 percent of the Federal budget, and that was the way it ought to be. If we could get him to understand that back then science education was 40 percent of the NSF budget, I'm sure that those numbers would reverse themselves pretty dramatically.

How much can we spend? I guess it's too vague a question but, given the kind of problem this is, we're spending 5 percent of the NSF budget. I guess the difficulty is that there are so many other players in this area that it's hard to feel the focused Federal responsibility, but has anybody made any estimates of what we would like to see in an NSF science education budget?

Mr. **Bloom**. I haven't made any specific estimates. I know that in some areas where I am conversant, they are funding one out of five good proposals. Materials development, research, and informal education at NSF is about $25 million for the next fiscal year. Doubling that would make a tremendous difference to America because NSF is a catalyst. We get a small NSF grant, and we take it around to every corporation in Philadelphia and tell them, "NSF has given their imprimatur to this. Why don't you buy in?" It's incredible leverage when NSF spends money, and NSF is willing to do pioneering things which other people are not willing to try, so it has an effect far beyond the amount of dollars. If you doubled that $25 million, it would make a huge difference in America.

Mr. **Walgren**. What are your thoughts on the general size of effort that might be reasonably provided?

Dr. **Fuller**. Well, obviously we are not close to meeting the kinds of needs that exist out there. Working at the undergraduate sector, we are really on the line. Some of the activities that we need support for are clearly education activities and some of them are in the research element, the research realm. We just need fair access to that field as well but from our point of view, if you were to move it back up to three or four times the current levels, the money would be spent very well.

Again, the point is that none of the institutions out there, none of the schools, none of the museums, are waiting for the Federal Government to do it all, but when the Federal Government does move, we just get things started. It's very hard to start them from out there. If you can get NSF to take the lead in the college science instrumentation program, for example, that grant will then produce two or three times that many dollars for college science instruments, and it's a lot easier to get those dollars when you've got the NSF grant as a lead.

Dr. **Paloumpis**. Mr. Chairman, of course I think you know that last year the community colleges and junior colleges were very, very supportive of the Walgren bill for community colleges. By and large, this is the kind of approach that we felt would help us to do the job that we have already started to do. As I mentioned in my testimony, we are not waiting for the Federal Government to get us started. We have started. We have to start. It's a matter that we can't always wait for someone to give us the money to start doing the things we are supposed to do.

But, nevertheless, in taking a look at the components that were in that original bill, I think there we see the very basic things that will help every one of us to continue to do the job we're doing and even do a better job than what we're doing. I think it's the kind of thing that helps us to bring in the equipment, to upgrade the faculty, and to also provide those kinds of programs and opportunities which will make us even more self-sufficient. I hope that we would not have to depend upon this kind of thing forever, but I think we do need this push at this point in time.

When you look at the statistics that we all are acquainted with, that our students are not as well prepared in science education today—they are at a lower level than they were when the Russians put up Sputnik—that really does scare us, and I think it's something we have to be concerned. When we are looking at the international competition, I think we have to be scared, and I think we have to start supporting what you had in that original bill.

Mr. **Walgren**. Does anybody have any experience with competition between the NSF and the Department of Education? We do some things through the Department of Education, and there is a sense that the NSF might be able to provide a different kind of leadership in a way. There are substantial resources in the Department of Education, but being administered in programs that don't have quite the flexibility and targetedness that we sense in NSF, in any event, or that might be able to be built into an NSF program. Would anybody like to comment about Federal dollars coming from both these agencies and the difficulties of the separation between the two?

Dr. **Paloumpis**. With the rarest of rare exceptions, informal education is not eligible for Department of Education support. That means museums, public television stations, and all these things which provide so much real education, are simply cut out completely from the Department of Education. It's to NSF's credit that there is an informal education support program.

Mr. **Walgren**. Other experience?

Dr. **Fuller**. I think our experience has been that science education, if it is really going to be effective, has got to involve scientists. If NSF has the lead, the scientists will be involved; if the Department of Education has the lead, it is much harder to get them to sign on to participate in the projects. It just doesn't have the same professional credibility.

That certainly would apply to the undergraduate sector. I don't think there is really a mission that the Department of Education ought to have for science at that level.

Even when you move down to the elementary and secondary level, I think one of the crucial needs there as we are trying to recruit and retain good science teachers is to recognize their professionalism, not just as teachers but also as scientists. NSF, I think, has to have an important role there because they give that professional credibility.

They have been funding just recently some very helpful projects, a couple of them on an experimental basis, to try to involve, for example, high school science teachers in research going on at colleges and universities, do that as a summer project for them and give them some professional standing as scientists, so when they go back into their classrooms they are talking about things they have done, not just things they have read about.

I think that is very important if we are going to solve that problem. We are not going to solve it exclusively with dollars—although they are an important part of the problem—certainly not with Federal dollars, but the Federal dollars certainly can help to enhance that sense of satisfaction and professional recognition which is now sadly lacking, particularly at the elementary and secondary level.

Dr. **Paloumpis**. I do want to concur partly, because I think that there is a special mission that the NSF has. I also think we have to be realistic. If all of these funds were put into the Department of Education and were made available, I think we would find them to be very, very reliable and we would feel as though they were very positive, and I think we would apply for those funds even though it was not National Science Foundation. But I think it is important that we recognize that there is a somewhat special function that is served by NSF, rather than by the Department of Education.

Mr. **Walgren**. Dr. Fuller, let me ask you about the general assessments of the state of instrumentation at 4-year undergraduate colleges. Do we have a needs assessment? How far behind are we?

Dr. **Fuller**. We don't have the formal needs assessment at the undergraduate level that we have completed at the research level. A couple of years ago there was a fairly extensive survey and study. That has only been brought together in bits and pieces. I can't give you it in some kind of concrete terms, but the problem is that it's a moving target. Everybody's equipment will be obsolete in 5 years, and you really still can't teach good science with obsolete equipment. It's just there is too great a contrast when the student leaves the classroom, goes into employment, or goes into that graduate lab. They have got to have seen similar things, so it's a continuing problem and I can't give you a magnitude for it at this point. I'm not sure that even trying to do a survey to get that magnitude would be all that helpful, because we know we are not even coming close at current levels to meeting the needs.

Mr. Walgren. What is your reaction to the problem that, when the size of a need is so great, that efforts to redress it that are only a fraction of a percent in coverage or effectiveness are almost a sell out or almost distract us from the fact that the problem is not being solved? I compare it somewhat to the Federal Government's reaction to housing needs for the elderly, where we build a number of units every year and yet for each unit there are 1,000 applications, and 1 person for the rest of their life gets the golden ring and 999 are left in whatever circumstances they were in, and we go around feeling that we did something for housing for the elderly. It seems a little wrong.

Dr. Fuller. Well, I think we get a little more hopeful picture when we're dealing with science and science needs at the elementary and secondary and the undergraduate level. First of all, when we do get Federal dollars put in at those levels, we get—as we have mentioned earlier—a significant payoff in leverage on those dollars. Those will attract other dollars from the private sector, from the States, so they make a larger contribution to the problem than they do if we were just counting on those dollars and their effect directly. There is a larger effect as well.

The other is that we're talking about making, in almost every case here, long-term investments in people—in the scientists who teach at the undergraduate level and in those undergraduates who go through and who choose science careers. There is a continuing payoff. When you make a specific level of investment, although the need is very large, it doesn't just stop with that particular project when it's through. It continues to be played out in the lives of those individuals who were affected by it, whose professional lives were enhanced by it.

Mr. Walgren. I see. Let me ask you, Dr. Fuller, as you know there is a proposal by the chairman of the full committee to provide matching funds for research facilities, academic research facilities. In the apprehension that in a peer-reviewed distribution of funds, the largest research universities would occupy all the funds for the facilities, there is a set-aside of 15 percent for what are at least not the largest in size of institutions, at least in terms as measured by receiving Federal research funds at the present time.

The difficulty is that that 15 percent that is set aside is almost exactly the participation of those smaller schools in the present range of distribution. How do you feel about that kind of set-aside? Is that the way to work against the problem of big science tending to concentrate by its very nature, rather than be distributed among the range of educational institutions that we obviously have an interest in supporting?

Dr. Fuller. It is the easiest way to make sure you get at least some recognition of a sector that you are afraid will be neglected, and I think it's very appropriate to be concerned that, because the needs are very large and certainly very real at the major research area, they can absorb lots more dollars very usefully. I think there is more that we ought to be investing, frankly, in that kind of basic civilian research, and most of it is concentrated at those major research centers. But to make sure that we don't skew the development of our whole science potential, I think it often is necessary to use some kind of a set-aside device to, among other things, be sure that we continue to have demonstrations of what those dollars will produce when they are spent on other kinds of projects.

That is probably the most telling way to—as we begin to fund, for example, more research done from scientists who teach at undergraduate institutions, that will have a cumulative effect. They will be encouraged, and they will have the opportunity to show other scientists in their own terms, by the quality of the research they do, what can be accomplished. But that doesn't just happen naturally out of the system these days because there are some inadequacies of the peer review system as it operates, so when you can put a special emphasis of some kind, whether it is a set-aside or a special program emphasis which allows us to demonstrate what can be done, then we can begin to make the case and let it happen in what we would hope would be the more natural way.

Mr. **Walgren**. Dr. Paloumpis, we have been concerned about this idea of scientific literacy and the specter of a population that is scientifically illiterate. As you say, the community colleges are an opportunity for one-half of the people who ultimately enter 4-year schools to gain some basic exposure to literacy and to the initial science awareness.

I wonder whether the community colleges have been able to address the concept of science literacy. Maybe it's too general at this point. I went to a conference the other day about scientific literacy and I didn't really hear it being defined in a targeted sense, but my question is whether or not there isn't some idea that we ought to start developing about what we would like to do with science literacy as a general proposition, and then be looking at the community colleges as a mechanism by which this could clearly be accomplished.

Dr. **Paloumpis**. I think that the science literacy is being addressed. It may not be addressed in those terms, and I would like to use a couple of examples of the kinds of things that are happening and not—although I will use my institution as an example—this is pretty much happening throughout the entire country.

We work as a very good bridge between the secondary school and the senior institution. We know that the problem is a very pervasive one, and it's not a very simple one that we know that we can solve just with the additions of money. That probably will not solve the problem.

In looking at our curriculum and working very closely with the high schools on their curriculum, and then working with the senior colleges for the transfer of our students on through into their curriculum, I think we now have a thread that has become very, very important. We have taken it very seriously, that there has been this lag in scientific literacy, so that now no student in our institution will ever go through the institution without having had math, at least at the college algebra level; science——

Mr. **Walgren**. At least at what? I'm sorry.

Dr. **Paloumpis**. College algebra level, as the bare minimum; without having science with laboratories. In fact, we are the only community college in the State of Florida right now that requires that every one of our science classes has a lab component that goes along with it. We feel very strongly about that.

We also take a look at all of the other areas that our students go into, in the allied health fields, the technology fields, that may not be in the college transfer, and we have taken the same approach, that there has to be that growth. One of the things that we are also doing—and, again, this is not unique with Hillsborough Community College in Tampa, but is a very common thing—where we are teaching courses in the high schools and supplementing the kinds of things that occur in the high school environment. Thank heavens the Florida State Legislature has seen fit to fund that kind of activity, so that the student stays in the high school, we provide advanced courses; the student not only gets high school credit but also gets college credit on the day that they graduate and come to us or to any other institution.

I think we are seeing that science literacy gap being shortened but, nevertheless, it has to be a very concerted effort in all areas. So I think that we are in a very unique position of seeing that bridge and helping the high school teachers, the elementary teachers, and then also taking those students from that point and also helping the senior institutions with a better product that they receive.

Mr. **Walgren**. Well, all right. Well, on behalf of the committee, let me thank you all for your participation.

Are there more of these? [Laughter.]

Not of these but, I mean, are there other little kits that the typical science museum has put together and offers for sale at their premises, I gather? Is that right?

Mr. **Bloom**. These are some things we have for you from other museums, and we have a lot of things in our place.

Mr. **Walgren**. Well, I would love to see them. I guess what I'm thinking is for the record we might describe some of them, and if there are catalogs of such things——

Mr. **Bloom**. I will be glad to send you some material on it, sir, for the record.

If I might comment on your drop-in-the-bucket question with a specific example, in the early eighties the National Science Foundation sponsored a traveling exhibition from the Exploratorium in San Francisco. I think it must have been a $50,000, $60,000, $70,000 grant. I don't have it in my head. The exhibit traveled for 5 years; it was seen by over 1 million people. In 1981 and 1982 it was in the Buhl Planetarium at Pittsburgh. It pulled the highest attendance in the history of the institution, inspired numerous school science fair projects and return trips to the museum, and the director of the museum says it made a permanent, positive effect on his museum.

There is now a newer version of it, supported by a generous grant from the IBM Co., called Seeing the Light in New York City, and it has been so popular that IBM had to put ads in the newspapers telling people not to come—a small NSF grant, multiplying, so it is a drop in the bucket but the drops add up.

Mr. **Walgren**. Interesting. Well, we are really interested in that, and we appreciate the contact we have had with you in this hearing process, and we will look forward to continuing it. Thank you all very much, gentlemen.

Dr. **Fuller.** Thank you, Mr. Chairman.

Mr. **Bloom.** Thank you, Mr. Chairman.

Mr. **Walgren.** Well, let's have the next panel come forward: Dr. Compton, Dr. Gray, Dr. Smelser, Dr. Malone, and Dr. David.

Welcome, gentlemen. Let's go in the order that I called, and the transcriber will have your name and association, I believe. Is that correct?

Dr. Compton.

STATEMENT OF DR. W. DALE COMPTON, SENIOR FELLOW, NATIONAL ACADEMY OF ENGINEERING

Dr. **Compton.** Thank you, Mr. Chairman. I would like to spend just a few minutes summarizing some of the events that led to the formation of the Engineering Research Centers, and then concentrate upon the issues that will influence the future of these centers.

The Engineering Research Centers were created in response to a general concern about the deterioration of our industrial competitiveness and the role that our research universities can play in attacking this important national problem. The report of the President's Commission on Industrial Competitiveness notes: "Technology propels our economy forward. Without doubt, it has been our strongest competitive advantage. America owes much of its standard of living to U.S. preeminence in technology."

But our pride in our technical accomplishments must be tempered by the realization that many of our technical competitors have been more effective in using new technology, even that generated by the United States, than has the industry of the United States. The more effective use of technology has thus become a key element in our national strategy to regain competitiveness in the world marketplace.

Although there has been much discussion of the role of the universities in the task of improving our overall competitiveness, the National Academy of Engineering has been unequivocal in its position on this matter. It has stated that:

> Many have debated the nature of the relationship between engineering research in universities and the technological competitiveness of industry. We are convinced that over the long term the knowledge base resulting from a strong and well-oriented university engineering effort undergirds the productivity and competitiveness of U.S. industry.

To bring university research to bear on problems affecting industrial productivity, it is critical for them to have a clear understanding of current industrial practice and its limitations. There is no better way to achieve this understanding than through the direct involvement of industrial people in the planning and conduct of research at the universities. With a growing awareness of the magnitude of the competitiveness problems, with the capability and willingness of many universities to contribute to the search for solutions, and with the recognition by many industries and universities that they can work productively together, a renewed sense of involvement between the universities and industry has emerged.

It is against this background that the National Science Foundation decided to create the Engineering Research Centers. In the Guidelines for Engineering Research Centers which was prepared for the National Science Foundation by a panel of the National Academy of Engineering, it was noted that:

> Two purposes underlie the Engineering Research Centers. One is to enhance the capabilities of engineering research universities to conduct cross-disciplinary research on problems of industrial importance. The other is to lessen one of several weaknesses in engineering education, an inadequate understanding by students of engineering practice—that is, the understanding of how engineering knowledge is converted by industry into societal goods and services.

The mission of the ERC's was seen to be to conduct cross-disciplinary research which will first lead to greater effectiveness and world competitiveness of U.S. industrial companies; second, to contribute to the education of engineers at all levels; and, third, to increase the number of graduating engineering students who can contribute innovatively to U.S. industry and its productivity.

In response to the formal announcement in 1984 of the intent of the National Science Foundation to establish a number of such centers, 142 proposals were submitted by 106 universities. Based upon extensive reviews of those proposals and visits to 14 university campuses for site visits, the National Science Foundation established the first 6 engineering research centers in April 1985.

The centers and their university affiliations are the following: A Systems Research Center jointly at the University of Maryland and Harvard University; a Center for Intelligent Manufacturing Systems at Purdue University; a Center for Robotics Systems in Microelectronics at the University of California at Santa Barbara; a Center for Composites Manufacturing Science and Engineering, jointly at the University of Delaware and Rutgers University; an Engineering Center for Telecommunications Research at Columbia University; and a Center for Biotechnology Process Research at MIT.

In the second year of the program 102 proposals were received from 78 universities. Based upon these, additional awards for new centers are anticipated within the next few months.

Now in reviewing the events of the past 2 years, I believe that it is important to understand that this new and somewhat revolutionary effort was undertaken by the NSF only after detailed consultation with both the university and the industrial communities. Further, it is important to understand that NSF has made a conscientious effort to follow the guidelines that were originally recommended by the National Academy of Engineering panel.

Now in contemplating the future of the Engineering Research Center programs, it is well to consider several matters. These were briefly noted in the original Academy report to the Foundation. Very briefly, these are, first, the fact that this is a new program, that it is pioneering, and that its goals and ambitions will demand more than the usual patience in awaiting and appraising the results. Second, support for the disciplinary bases of engineering research by Federal, State, and private sectors must continue. Third, the problems of engineering education are numerous and severe, and this program is an important but only one step toward solving some of them. And, finally, those administering the program must allow the centers considerable latitude in attaining their goals.

The total NSF budget request for the Engineering Research Center for fiscal year 1987 is $35 million. This is an increase of $12 million over the currently planned expenditures for fiscal year 1986. This increase would allow the addition of three to five more new centers. Depending upon the final number of new centers that will be established in 1986, this could bring the total to about 15.

Now in view of the deficit issues that must be addressed in the fiscal year 1987 budget, it is probably worthwhile to pose several specific questions about the desirability of expanding this program further.

First, is the program continuing to meet key national objectives? In view of the need to address the industrial productivity issues in new and imaginative ways and to develop tools that can be used to attack these programs, the principal thrust of the ERC's toward these objectives clearly support the national interest. Further, the centers have addressed the issue of improving the quality of engineering education and of providing students and faculty members with an improved mechanism for interaction with the industrial sector.

As a second question, is the program receiving support from both the university and the industrial communities? The number of high-quality proposals submitted by universities continues to greatly exceed the number that can be funded. It seems clear that the universities view the program as fulfilling a genuine need. Further, these proposals each contain elements of industrial involvement. The preparation of the proposals has already led to a furthering of the interactions between the campus researchers and their counterparts in industry.

Is the program attracting high-quality faculty members and students? In general, the participants in the program have been the leaders in university engineering research. The program has also attracted faculty members from disciplines that do not normally interact, and thus the cross- disciplinary nature of the research has been enhanced.

Should the number of Engineering Research Centers continue to be increased, even in a period of budget restrictions? The ERC's are an experiment that gives every sign of contributing to the solution of important national problems, of enhancing the interaction of industry and universities, and of improving the learning experience of students. The NSF has placed a high priority on this program, as evidenced by its intention to single it out for expansion. All of the experience to date suggests that the Foundation has good reason to give it this kind of priority.

How should the priorities be adjusted if additional money is not available in fical year 1987? Clearly the first objective should be to continue to support those centers that have already been established. Continuity is a key to the success of this process. Every effort must be made not to reduce the viability of the already established centers.

As you consider the appropriations for the National Science Foundation for fiscal year 1987, I trust that you will carefully weigh the importance of continuing the strong support for our long-range national research effort. The National Science Foundation is the bastion of basic research in this country. The health of both our sciences and our engineering depend upon the basic support that the Foundation provides.

Thank you for this opportunity to discuss this important experiment in the support of cross-disciplinary engineering research in our universities.

[The prepared statement of Dr. Compton follows:]

TESTIMONY BEFORE THE U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY
SCIENCE, RESEARCH AND TECHNOLOGY SUBCOMMITTEE

by
W. DALE COMPTON
SENIOR FELLOW, NATIONAL ACADEMY OF ENGINEERING
FEBRUARY, 26, 1986

It is a great pleasure to appear before you and to offer some thoughts concerning efforts at the National Science Foundation (NSF) to expand its support of engineering research through the establishment of Engineering Research Centers. I would ask that these comments be considered within the context of the general concern about the deterioration of our industrial competitiveness and the role that our research universities can play in attacking this important national issue.

Among our many national accomplishments are the outstanding successes achieved in the creation of fundamental scientific knowledge. There is also cause for great pride in the development of new and important technology from our achievements in science. As was so clearly stated in The Report of the President's Commission on Industrial Competitiveness:

> Technology propels our economy forward. Without doubt, it has been our strongest competitive advantage. Innovation has created whole new industries and the renewal of existing ones. State-of-the-art products have commanded premium prices in world markets, and technological advances have spurred productivity gains. Thus, America owes much of its standard of living to U.S. preeminence in technology. (President's Commission on Industrial Competitiveness, 1985, Vol.1, p. 18)

But our pride in our technical accomplishments must be tempered by the realization that many of our international competitors have been more effective in using new technology, even that generated by the United States, than has the industry of the United States. The more effective use of technology has thus become a key element in our national strategy to regain competitiveness in the world marketplace. But this task does not belong to our industries alone. The universities also must play a role.

The National Academy of Engineering noted in its report *New Directions for Engineering in the National Science Foundation*:

> Many have debated the nature of the relationship between engineering research in universities and the technological competitiveness of industry. We are convinced that, over the longer term, the knowledge base resulting from a strong and well-oriented university engineering effort undergirds the productivity and competitiveness of U.S. industry. Perhaps even more importantly, research provides the environment within universities that anchors quality engineering education, for it enables engineering faculty and advanced students to deepen and broaden their knowledge and to develop their capacity for creative work. (National Academy of Engineering, 1985, p. 1).

The universities play multiple roles in assisting this nation to regain its competitive leadership. Briefly stated, these roles are, first, to train people, both the entering student who is learning a new subject and the returning student who seeks an update or refresher; second, to conduct research that contributes to the fundamental understanding of phenomena; and third, to transfer technology generated in the research laboratory to industry where it can be used in creating new products and processes. While the last of these roles clearly involves an interaction between the university and industry, the role of industry in helping to define and carry out the university research programs is perhaps less obvious.

To bring university research to bear on problems affecting industrial productivity, it is critical to gain a clear understanding of current industrial practice and its limitations. There is no better way to achieve this understanding than through the direct involvement of industrial people in the planning and conduct of research at universities.

Although such direct involvement might seem to be perfectly straight forward, it has not been easy to accomplish. Until recently, industrial support of university research has been modest. Interactions have often been limited to an occasional visit for the recruitment of students or for the presentation of a philanthropic gift. Substantive involvement in university research programs was a rarity.

There were many reasons for this lack of industrial involvement. Two of the most often cited are an unwillingness on the part of industries to commit their best people to spending large amounts of time on campus and an often-voiced concern that university research is so long-range and so general that it is of only limited interest to industry. Thus the barriers to interaction between the universities and industry have grown. With the federal government as the principal source of funding for research there were few incentives for either the universities or the industries to eliminate those barriers.

It might even have been concluded that it was unnecessary to break through the barriers if the faculty members of engineering schools had industrial experience. For then the universities could have done the task without the help of industry. Unfortunately, few faculty members have had experience in industry. Thus, many universities found themselves attempting to create new programs in support of industrial productivity with neither sufficient experience nor the benefit of industrial advisers.

Fortunately, this situation has begun to change in recent years. With the growing awareness of the magnitude of the competitiveness problems, with the capability and willingness of many universities to contribute to the search for solutions, and with the recognition by many industries and universities that they can work productively together, a renewed sense of involvement between the universities and industry has emerged.

It is against this background that the National Science Foundation decided to create the Engineering Research Centers. In Guidelines for Engineering Research Centers, a report to the National Science Foundation, a panel of the National Academy of Engineering noted that:

> Two purposes underlie the Engineering Research Centers (ERC's). One is to enhance the capacities of engineering research universities to conduct cross-disciplinary research on problems of industrial importance. The other is to lessen one of several weaknesses in engineering education: an inadequate understanding by students of engineering practice; that is, the understanding of how engineering knowledge is converted by industry into societal goods and services. (National Academy of Engineering, 1984, p.1).

The report went on to discuss the Mission of the Centers.

> The goal of the Centers is to improve engineering research so that U.S. engineers will be better prepared to contribute to engineering practice and to assist U.S. industry in becoming more competitive in world markets. Thus, engineering research and education must be firmly linked in these Centers, and they must be judged by their success in achieving this linkage. While the Centers will differ from one another, reflecting their home institutions, people, and programs, their mission must have some common traits. First, specific working ties with industry must provide a continual interaction of academic researchers, students, and faculty with their peers, namely, the engineers and scientists in industry, to assure that these programs remain relevant to the needs of the engineering practitioner and that they facilitate and promote the flow of knowledge between the academic and industrial sectors. Second, the programs of each Center must emphasize the synthesis of engineering knowledge; that is, the programs should seek to integrate different disciplines in order to bring together the requisite knowledge, methodologies, and tools to solve problems important to engineering practitioners. Third, the programs must contribute to the increased effectiveness of all levels of engineering education.
>
> Against these common traits, the panel sees the mission of the ERC's as conducting cross-disciplinary research which will:
>
> - o lead to greater effectiveness and world competitiveness of U.S. industrial companies...
> - o contribute to the education of engineers at all levels,...
> - o increase the number of graduating engineering students who can contribute innovatively to U.S. industry and its productivity...(National Academy of Engineering, 1984, p.3)

Considering this proposed mission for the ERC's, the NSF issued, in early 1984, a formal announcement of its intent to establish a number of such Centers. The response to this request was both suprising and gratifying. A total of 142 proposals were submitted from 106 universities. Clearly the university community viewed this as an opportunity to join in a new program that was both exciting and of far-reaching importance.

Faced with the difficult task of choosing among a collection of fine proposals, the Foundation assembled a distinguished panel to offer advice and counsel in selecting the first group of universities to receive awards. The panel cochairmen were C. Lester Hogan, former President of Fairchild Camera and Instrument Corporation and Eric A. Walker, former President of Pennsylvania State University.

Dr. Walker has indicated that the panel used a number of criteria in arriving at its recommendations. He has summarized the key criteria as follows:

> 1. The research must involve a team effort of individuals from various backgrounds, possessing different engineering or scientific skills. The research should represent an effort that can best be accomplished through cross-disciplinary research. It should not be a collection of individual research projects.
>
> 2. The Center should include a significant educational component involving both graduate and undergraduate students in research activities in the Center.
>
> 3. The Center should focus on research opportunities aimed at developing fundamental knowledge in areas critical to U.S. competitiveness in world markets.
>
> 4. There should be provision for participation by industry engineers and scientists in Center research activities. State and local agencies and government laboratories might also be participants; provision for such participation in a proposal would add to its strength. (National Research Council, 1986, p.46)

Based upon extensive reviews of the proposals and visits to 14 university campuses for site visits, the NSF established the first six Engineering Research Centers in April 1985. The Centers and the University affiliation are:

Systems Research Center--University of Maryland and Harvard University (Joint)
Center for Intelligent Manufacturing Systems--Purdue University
Center for Robotics Systems in Microelectronics--University of California at Santa Barbara
Center for Composites Manufacturing Science and Engineering--University of Delaware and Rutgers University (Joint)
Engineering Center for Telecommunications Research--Columbia University
Biotechnology Process Engineering Center--Massachusetts Institute of Technology

Although additional awards for new Centers are anticipated in 1986, the review process is not yet complete and the final decisions have not been made. It is worthy of note, however, that interest in the program continues to be high with 102 new proposals received from 78 universities. An additional 75 affiliates, mostly other universities, were associated with this group of 78 principal institutions. A review process similar to that just described for the 1985 awards is being followed for 1986. Site visits have been made to 15 university campuses for the purpose of reviewing the detailed proposals.

I have discussed, at some length, the events that led up to the establishment of these Centers. I believe that it is important to understand that this new and somewhat revolutionary effort was undertaken by the NSF only after detailed consultation with both the university and the industrial communities. Furthermore, it is important to understand that NSF has made a conscientious effort to follow the guidelines that were originally recommended by the National Academy of Engineering panel.

In contemplating the future of the Engineering Research Center Programs, it is well to consider several matters. These were briefly noted in the original National Academy of Engineering report to the National Science Foundation on the Guidelines for Engineering Research Centers. These are:

> The fact that this is a new program, that it is pioneering, and that its goals are ambitious will demand more than the usual patience in awaiting and appraising results.
>
> Support for the disciplinary bases of engineering research by federal, state, and private sectors must continue.
>
> The problems of engineering education are numerous and severe, and this program is an important step toward solving some of them.
>
> Those administering the program must allow the Centers considerable latitude in attaining their goals...(National Academy of Engineering, 1984, pp.13-14)

The total NSF budget request for the Engineering Research Centers for FY 1987 is $35 million. This is an increase of $12 million over the currently planned expenditure for FY 1986. This increase would allow the addition of 3 to 5 more new Centers. Depending upon the final number of new Centers that will be established in 1986, this could bring the total number of Centers to about 15.

In view of the deficit issues that must be addressed in the FY 1987 budget, it is worthwhile to ask several specific questions about the desirability of expanding this program further:

Is the program continuing to meet a key national objective?

> In view of the need to address the industrial productivity issues in new and imaginative ways and to develop tools that can be used to attack these problems, the principal thrust of the Engineering Research Centers toward these objectives clearly support the national interest. Further, the Centers have addressed the issue of improving the quality of engineering education and of providing students and faculty members with an improved mechanism for interaction with the industrial sector.

Is the program receiving support from both the university and the industrial communities?

> The number of high-quality proposals submitted by universities continues to greatly exceed the number that can be funded. It seems clear that universities view the program as fulfilling a genuine need. Further, these proposals each contain elements of industrial involvement. The preparation of the proposals has already led to a furthering of the interactions between the campus researchers and their counterparts in industry.

Is the program attracting high quality faculty members and students?

> In general, the participants in the program have been the leaders in university engineering research. The program has also attracted faculty members from disciplines that do not normally interact. Thus the cross-disciplinary nature of the research has been enhanced.

Should the number of Engineering Research Centers continue to be increased in a period of budget restrictions?

> The Engineering Research Centers are an experiment that gives every sign of contributing to the solution of important national problems, of enhancing the interaction of industry and universities, and of improving the learning experience of students. The National Science Foundation has placed a high priority on this program, as evidenced by NSF's intention to single it out for expansion. All of the experience to date suggests that the Foundation has good reason to give it this kind of priority.

How should the priorities be adjusted if additional money is not available in 1987?

> Clearly the first objective should be to continue to support those Centers that have already been established. Continuity is a key to the success of this process. Every effort must be made not to reduce the viability of the already established Centers.

As you consider the appropriations for the National Science Foundation for FY 1987, I trust that you will carefully weigh the importance of continuing the strong support for our long-range national research effort. The National Science Foundation is the bastion of basic research in this country. The health of both our sciences and our engineering depends upon the basic support that the National Science Foundation provides.

Thank you for this opportunity to present these thoughts on this important experiment in the support of cross-disciplinary engineering research in our universities.

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Dr. **Gray**. Do you want to go to me or have questions?

Mr. **Walgren**. Let's go to you. I think in fairness we ought to get all the statements in.

Dr. **Gray**. Thank you. George Pimentel would have liked to have been here in person, but he is recovering from surgery, and he sends his regards to you, Mr. Chairman.

Would you like me to read or would you like me to talk?

Mr. **Walgren**. I think talking would be better.

Dr. **Gray**. Wonderful.

Mr. **Walgren**. What I want is, I want witnesses to do what they want to do.

Dr. **Gray**. I would like the record to show that the chairman has asked me to talk. [Laughter.]

Mr. **Walgren**. Whatever you feel comfortable with.

STATEMENT OF DR. HARRY B. GRAY, ARNOLD O. BECKMAN PROFESSOR OF CHEMISTRY, DEPARTMENT OF CHEMISTRY, CALIFORNIA INSTITUTE OF TECHNOLOGY

Dr. **Gray**. I am a member of the committee to survey opportunities in the chemical sciences. It was a committee organized by the Office of Chemical Sciences and Technology of the National Research Council of the National Academy of Sciences, and we put out a report that I am holding up. Bob Simon, who is here with me, who is now holding up his hand, those of you who haven't read this report of ours, I urge you to do so, and Bob will be happy to take anyone's name and send you a copy of this report. This is the best I can do. I don't have any of the things that make heat right now. [Laughter.]

I wish I did, actually. Those were very nice.

Well, you may be wondering what is happening in chemistry, and why Mr. Bloch of the National Science Foundation has in fact called out chemistry as one of the high-priority areas, and I would like to tell you.

We have to go back to right after World War II, when chemistry was somewhat in the doldrums. It was at that time largely empirical. I think in my testimony, in my written testimony, which you can also have copies of if you see Bob or anyone else, I refer to it as the "test tube and bunsen burner" era in chemistry. I also like to refer to it as the "shake and bake" era. We threw things together and hoped something came out that was interesting.

Things have changed. What has happened is that there have been two revolutions that relate directly to chemistry. The first one I refer to is the instrumentation revolution that has occurred since World War II, in the 40 years from then to now. The second one is the one I would call the synthesis revolution

What are these revolutions? Well, we now have high-speed computers that we are using all the time in chemistry. We now have lasers that allow us to look at chemical reactions at times even less than one-trillionth of a second. We have big nuclear magnetic resonance spectrometers. We have all manner of very impressive, sophisticated instrumentation, and chemists are now utilizing these computers and instrumentation as never before in history. This is the instrumentation revolution and what it has done for chemistry.

On the other side there is the synthesis revolution. Whereas 40 years ago we threw things together, the whole business of chemistry was highly empirical, now the emphasis is on—in organic chemistry and inorganic chemistry and in biological chemistry—is on design, design and then synthesis. That is, we are to the point now in sophistication where we can actually make molecules that we can put up on computer screens and look at. We can move the atoms in and out, and we are almost to the point that we can make materials with desired properties. This is the synthesis revolution.

Organic chemists and inorganic chemists and biological chemists are coming together to make hybrid molecules. In my testimony is an example of that from my own work, where inorganic synthesis and biological, if you like, genetic engineering type synthesis is brought together to make a super type molecule with desired properties.

What does this mean for the country? It means the following: What has happened with the instrumentation revolution and the computer revolution has led to chemists, theoretical chemists and experimental chemists, understanding chemical reactions at the atomic level, in very, very short times, at the very early stages, in trillionths in stages. We now understand these reaction pathways better than we ever have before.

On the other side, organic chemists and inorganic chemists and biochemists are making molecules with computer aid, with computer graphics and design, and then synthesized with desired properties. These two areas are coming together to create two major new forces that the country has to pay attention to because it is going to make a tremendous difference in our competitive position, in our national defense, et cetera, et cetera.

These two new areas that are coming out I would call the new materials chemistry, where we are going to be able to make new structural materials, new magnetic materials, new optical materials, new conducting materials—semiconductors, superconductors—and, I should emphasize, we are going to be able to finally make materials with desired properties that can withstand extremes of temperature and pressure, materials that we can actually predict how they are going to perform under certain stress conditions. I don't have to underscore how important that is, in view of recent events.

Second, on the other side there is coming, because of these two revolutions, a chemically driven, a new chemically driven biotechnology which is already having a big impact in the synthesis of new drugs for disease control and in food production.

All of these points that I am making now are developed and documented in this Pimentel report, and I urge you to look at it because of its importance.

What are the priorities? The priorities we have called out, for the reasons I have given, are in instrumentation—for the National Science Foundation, I should emphasize. What comes out of this document for the National Science Foundation are priority areas in instrumentation, in analytical methods, in theory, in synthesis, and the chemistry of life processes. All of this will make us much more competitive and develop the areas, the interface areas, that have to be developed at the interface between chemistry and engineering which is coming because of this new materials chemistry and, on the other side, the interface between chemistry and biology, what I am now calling this new chemically driven biotechnology.

What about education? Education is so important that I want to read, if you will permit me, from part of my testimony:

> In chemistry, we have an educational process that effectively furnishes the stream of talented and well-prepared young scientists essential to the continued vitality of the Nation's technology enterprise. Our industries rely upon them—on their entering the field and bringing an immediate familiarity with the latest discoveries, the recent scientific literature, and the newest instruments and scientific techniques. Herein lies a substantial basis for the investment of Federal resources in the fundamental chemical research conducted in the Nation's universities. A main reason for the urgency to increase funding now for basic chemical research in our colleges and universities is the need to provide the best training possible to the current generation of graduate students. If we fail to act now, we risk losing an entire generation of talent.

Now what about the National Science Foundation fiscal year 1987 budget? Our committee feels that Mr. Bloch has been very responsive to the opportunities that have been called forth. In our document we commend Mr. Bloch—and he is not a chemist—we commend Mr. Bloch for his very careful analysis of the situation and the real opportunities now in the chemical sciences for the country, to wit, and I shall now quote:

> Specific increases being requested for the chemistry division seem to be very much in line with the recommendations that we have made.
>
> The requested increase for shared instrumentation would allow the Foundation to make a start on providing needed support for ongoing maintenance and operation expenses.
>
> The enhancement for collaborative research activities aimed at advancing materials chemistry, chemical catalysis, and new chemical instrumentation will help in some of the priority areas identified in our report. I am pleased that the Foundation is not now proposing too large a shift in the direction of collaborative research activities, because much time and effort is required to develop truly synergistic collaboration. The vigor of

And I underscore this—

> The vigor of chemical research in this country is likely to continue to be based on individual faculty members working with their students. NSF must continue to allow creative working scientists to decide independently where the best prospects lie for acquiring significant new knowledge. While collaborative projects do not necessarily constrain individual initiative, one should be cautious about shifting the balance too much.

I think we are shifting it just right right now, and the budget reflects that, and Mr. Bloch should be commended on this point. Next bullet:

> The Chemistry of Life Processes initiative was started in fiscal 1985, following an interim report prepared at the request of OSTP and NSF by a committee led by Pimentel under the auspices of the Academy's Committee on Science, Engineering, and Public Policy. This activity, along with the new enhancement for biomimetic chemistry, will accelerate progress in understanding biotechnology at the most fundamental molecular level.
>
> Although computational chemistry is not called out separately as a priority area in our report, we recognized that computational activities were key to progress in each of the priority areas that were identified.

I would like to point out now that since the Pimentel report was published, we have held five discussion meetings with chemical colleagues in different regions of the country to provide a forum for debating the report's findings and recommendations. It is a testimony to George Pimentel's leadership and the 350 chemical researchers who suggested topics, prepared commissioned papers on cutting-edge research, or critiqued drafts of the report as it developed, that we have yet to identify a major controversy on the report's recommendations. We have had lots of lively arguments on how chemists can communicate more effectively in the science policy arena, but we seem to have a consensus for the first time on priorities.

Thank you.

[The prepared statement of Dr. Gray follows:]

February 26, 1986

Testimony on Opportunities in Chemistry

by Harry B. Gray

before the

Subcommittee on Science, Research and Technology

of the

Committee on Science and Technology
House of Representatives

Honorable Doug Walgren, Chairman

Mr. Chairman and Members of the Committee

My name is Harry Gray, and I am a Professor of Chemistry at the California Institute of Technology. I served on the Committee to Survey Opportunities in the Chemical Sciences that was chaired by George Pimentel. This committee of 26 members - broadly representative of the academic, industrial, and government research sectors, the geographic areas, and the major subdisciplines of chemistry - was organized by the Board on Chemical Sciences and Technology of the National Research Council of the National Academy of Sciences.

The charge to the committee was to describe the contemporary research frontiers of chemistry, the opportunities for the chemical sciences to address society's needs, and the resources needed to explore these frontiers to advance human knowledge and to exploit chemistry's potential for enhancing the well-being of all humankind.

The final report of our committee was published by the National Research Council this past October following intensive review and approval by a panel of peers from other scientific disciplines as well as from chemistry according to procedures of the Academies' Report Review Committee. Appendix A contains the Executive Summary of the report.

You have asked me to provide a brief overview of this report and to comment on the National Science Foundation's FY 1987 Budget request to the Congress. I will do my best to convey the excitement of modern chemical research that is the heart of the report and to summarize the recommendations we have made, particularly those pertaining to the National Science Foundation. My comments are offered on behalf of the Committee to Survey Opportunities in the Chemical Sciences and its parent Board on Chemical Sciences and Technology.

FRONTIERS IN CHEMISTRY

Chemistry is the science of molecules - how they are made, how they are transformed into valuable new products and materials, and how they can be used safely to improve the quality of life for all humankind.

Molecules and their transformations are central to almost every aspect of our quality of life, and economic strength, yet there remains much that we do not know about the rules that control the molecular game. You can see this clearly in the search for a cure for AIDS, in the questions surrounding the Shuttle disaster, in the search for environmentally sound approaches to the production and preservation of food, and in the search for improved molecular level switching devices for computers and communication devices.

As chemists we are both excited and awed by the recent accomplishments and anticipated discoveries on the horizon at a number of chemistry's frontiers. In the report we call particular attention to current opportunities in chemical kinetics, chemical theory, catalysis, materials, synthesis, life processes, and analytical methods. These are really not new research areas. What is new is an arsenal of now available tools - highly sophisticated instruments - that allow us to explore at the molecular level problems that were previously intractable. The new tools, which include high resolution nuclear magnetic resonance spectrometers, lasers, and computers, are essential - absolutely essential - to make headway in the priority research areas identified in the report.

INTELLECTUAL CHALLENGES

The report contains numerous examples of opportunities for intellectual advances in the chemical sciences. But in this setting it is neither possible nor appropriate to try to describe more than a few examples of the range of opportunities that we see for instance in controlling chemical reactivity. A common element is our developing ability to probe the elemental steps of chemical change and to deal with extreme molecular complexity.

Let me mention one example from my own research area that may help you understand the kinds of problems that chemists are now able to address. The research question in its simplest form is this: What is the relationship between distance and electron-transfer rates within molecules? While the question is easily stated, inventing an experiment that will yield the information needed to help us answer the question unambiguously is much more difficult. Recently Judy Campbell, John Richards and I have discovered an experimental approach that has an excellent chance of giving us the answers we need.

The approach builds on some basic chemistry of the element, ruthenium, that has been developed in my laboratory over the past decade. The positioning of ruthenium atoms in a molecule is controlled using site-directed mutagenesis, a technique from the biotechnology arsenal that enables us to design novel proteins.

This part of the work is an extension of the research programs in Judy's and John's labs. The basic idea behind the experiment is to use the ruthenium atom as the source of the electron to be transferred, use a laser to trigger the transfer of the electron from one metal atom to another at a fixed and known distance, and then monitor the dynamics of the transfer process as a function of time.

This may sound like a very simple experiment. And it would be easy to carry out were it not for the extreme molecular complexity of the system with which we must deal. At times we wish that "Mother Nature" were a little less complex; but without this complexity we could not have life as we know it.

The molecular level detail that we are trying to uncover in this research program is central to advances in understanding electron transfer processes and how energy is stored efficiently in living systems.

SOCIETAL BENEFITS FROM CHEMISTRY

Chemistry is a central science that responds to societal needs. It is critical in our attempts to discover new processes, tap new sources of energy, develop new materials, feed the world's population, improve health and conquer disease, monitor and protect our environment, maintain our economic competitiveness, and increase our national security. Because of this responsiveness to human needs, chemistry has become a crucial element in the nation's well-being. The Chemicals and Allied Products industry employs more than a million people, makes annual shipments totalling about $175 billion, and currently displays about a $10 billion positive international balance of trade, second highest of all commodity groups.

Examples of the contributions of chemical research to the solution of important societal problems are provided in the Executive Summary (Appendix A) and in a series of brief vignettes in Appendix E.

RECOMMENDATIONS

The report contains eleven specific recommendations. These, and the rationale for them, are all in the Executive Summary of the report (Appendix A).

The first recommendation calls out priority research areas that the committee believes are especially promising and that should receive special attention, particularly from the relevant mission agencies.

But the report cautions that listing priority areas carries the risk of quenching some adventurous new directions with potential yet to be recognized. It urges that we regard our research support as an investment portfolio designed to achieve maximum gain. A significant part of the investment should be directed toward recognized priority areas but with a flexibility that encourages evolution as new frontiers emerge. A second substantial element in this portfolio should be support of creative scientists who propose to explore new directions and new ideas.

The second and third recommendations deal with the important issue of improving the research and funding links between industry and academic research.

The remaining recommendations all deal with the funding that is necessary to make it all happen. They focus on chemistry in relation to various federal agencies' missions.

The problem for the Nation is that the current investment in basic chemical research is still historically rooted in a funding pattern that was appropriate to a "test-tube and Bunsen burner era." That era is long past. Today chemical research instrumentation is expensive to purchase and to operate, but the cost-benefit ratio for humankind is high. Philip Abelson in an editorial in SCIENCE magazine titled, "Federal Support for Chemistry," made the following observation, "Important progress is being made in chemistry. In proportion to its contribution to the advancement to other sciences and its contributions to the economy, chemistry is the most underfunded of the natural sciences." (Appendix B)

THE FEDERAL ROLE IN FUNDAMENTAL RESEARCH

In developing our recommendations for action, the Pimentel Committee recognized that, although industry can itself engage in only a modest amount of the most fundamental and adventurous research because the time horizon for application is remote, it plays an important role in the funding of university chemical research. In this regard we are very pleased that over the past three years industry has increased its funding of basic chemical research in colleges and universities by about a factor of four from $10 million in 1981 to about $40 million in 1985. This industrial support, though modest in total, is extremely important because it facilitates movement of new discoveries into new applications and influences university research agendas. The Council for Chemical Research, made up of representatives from most academic research institutions and from chemical industry, has been effective in improving academic - industrial communication and research funding. But industry can not be expected to pick up the check for long-term, high-risk research activities that are not yet perceived to be important to their future or where they are unlikely to be able to recover a reasonable portion of the benefits to be derived from that research support. It is an appropriate place for public investment, and thus the report calls on the Federal Government both through the mission agencies and the National Science Foundation to increase its support of chemical research.

DOCTORAL EDUCATION IN CHEMISTRY

Although the report focusses primarily on the U.S. research enterprise in the chemical sciences, the well spring of vitality of this enterprise is and always will be the continued entrance of an adequate number of brilliant young scientists. Thus, we are inevitably drawn to examine the health of the educational system that attracts top calibre individuals, nurtures their creativity, and effectively prepares them for their professional careers. And, undoubtedly, the higher levels of professional activity in chemistry depend directly on experiences embodied in the Ph.D. program. This dependence is rooted in the rapid pace of scientific progress over the span of a chemist's professional career. The pace requires ability to cope effectively with and develop new ideas.

In chemistry, we have an educational process that effectively furnishes the stream of talented and well prepared young scientists essential to the continued vitality of the nation's technology enterprise. Our industries rely upon them - on their entering the field and bringing an immediate familiarity with the latest discoveries, the recent scientific literature, and the newest instruments and scientific techniques. Herein lies a substantial basis for the investment of federal resources in the fundamental chemical research conducted in the nation's universities. A main reason for the urgency to increase funding now for basic chemical research in our colleges and universities is the need to provide the best training possible to the current generation of graduate students. If we fail to act now, we risk losing an entire generation of talent.

THE ROLE OF THE NATIONAL SCIENCE FOUNDATION: NSF FY 1987 BUDGET

The section of the report dealing with the National Science Foundation is in Appendix C. This is a good point to turn our focus to the Foundation's FY1987 budget request. That request is like the proverbial good news - bad news story. The good news is that increases are requested for important purposes, but the bad news is that the magnitude of the increases is considerably smaller than the needs outlined in the report.

Although chemists understand that budget increases are difficult to justify in a budget climate such as the Nation now finds itself, we believe, nevertheless, that the case for increased Federal funding for basic chemical research in our Nation's Colleges and Universities is compelling. Thus, even if it should not be possible to increase the total Federal investment in R&D, tradeoffs to better serve the nation's economic competitiveness, within this total (i.e., not just NSF), are needed.

Specific increases being requested for the Chemistry Division seem to be very much in line with the recommendations that we have made.

o The requested increase for shared instrumentation would allow the Foundation to make a start on providing needed support for ongoing maintenance and operation expenses. We agree wholeheartedly with the goal of doubling the size of this program.

o The enhancement for collaborative research activities aimed at advancing materials chemistry, chemical catalysis, and new chemical instrumentation will help in some of the priority areas identified in our report. I am pleased that the Foundation is not now proposing too large a shift in the direction of collaborative research activities, because much time and effort is required to develop truly synergistic collaboration. The vigor of chemical research in this country is likely to continue to be based on individual faculty members working with their students. NSF must continue to allow creative, working scientists to decide independently where the best prospects lie for acquiring significant new knowledge. While collaborative projects do not necessarily constrain individual initiative, one should be cautious about shifting the balance too much.

o The Chemistry of Life Processes Initiative was started in FY1985 following an interim report prepared at the request of OSTP and NSF by a committee led by Pimentel (Report of the Research Briefing Panel on Selected Opportunities in Chemistry) under the auspices of the Academies' Committee on Science, Engineering, and Public Policy. This activity along with the new enhancement for biomimetic chemistry, will accelerate progress in understanding biotechnology at the most fundamental molecular level.

o Although computational chemistry is not called out separately as a priority area in our report, we recognized that computational activities were key to progress in each of the priority areas that were identified (i.e., Understanding Chemical Reactivity, Chemical Catalysis, Chemistry of Life Processes, Chemistry Around Us, and Chemical Behavior Under Extreme Conditions).

COMMUNITY CONSENSUS

I would like to point out that since the Pimentel Report was published we have held five discussion meetings with chemical colleagues in different regions of the country to provide a forum for debating the report's findings and recommendations. It is a testament to George Pimentel's leadership and the 350 chemical researchers who suggested topics, prepared commissioned papers on cutting-edge research, or critiqued drafts of the report as it developed, that we have yet to identify a major controversy on the report's recommendations. We have had lots of lively arguments on how chemists can communicate more effectively in the science policy arena, but we seem to have a consensus on priorities.

The reaction to the report from industrial representatives has been very positive. I would like to call your attention to a recent guest editorial in SCIENCE magazine (Appendix D). In this editorial, E. G. Jefferson, Chairman of the Board, E.I. du Pont de Nemours & Company, states, "All who are concerned that science make its full contribution to national life should study this report and its recommendations. They will be convinced that we need full support of the chemical sciences by government, industry and our academic institutions. Society will be repaid manyfold for such an investment of resources."

Our competitiveness in a range of international markets depends upon our maintaining our present position of leadership in the chemical sciences. There is no area of basic science that offers a more secure investment in the nation's future. And our allies and economic competitors among the technologically advanced countries -- Japan, Germany, Sweden, France, and Britain -- have expressed considerable interest in this report. They are ready to move forward rapidly in implementing its recommendations and accelerating their efforts in chemical research.

I would urge you to do what you can to find a way for us to make the recommended investments in the future - a future that will be very much influenced by what we know about molecules. And the cost is miniscule when weighed against the potential returns. We must encourage a scientific field brimming with opportunities for discovery that will advance human knowledge and strengthen the underpinnings of a major industry, and we must attract a substantial share of our brightest young scientists to this rewarding task.

List of Appendixes:

A. Executive Summary of Report
B. Abelson Editorial
C. Section of Report on NSF
D. Jefferson Editorial
E. Vignettes

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OPPORTUNITIES IN Chemistry

Committee to Survey Opportunities in the Chemical Sciences

Board on Chemical Sciences and Technology

Commission on Physical Sciences, Mathematics, and Resources

National Research Council

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Washington, D.C. [illegible]

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CHAPTER I

Introduction

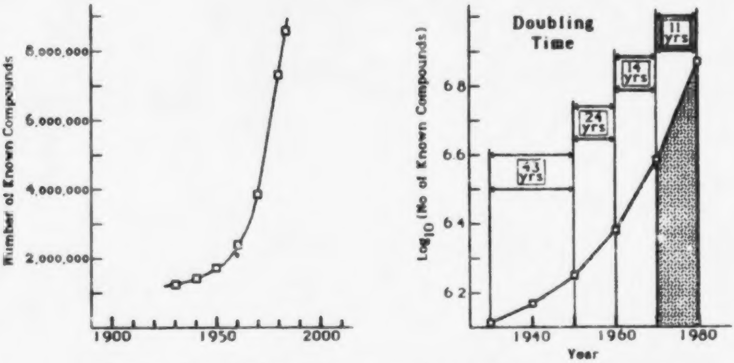
Two decades have passed since the publication of NRC Report 1292, *Chemistry: Opportunity and Needs*, edited by Frank H. Westheimer. The frontiers that it envisaged in 1965 have indeed fulfilled their promise, and almost all of the report's optimistic expectations have been realized. In fact, the advances have been so rapid and so penetrating that the structure of chemistry and its interactions with contiguous disciplines have qualitatively changed. Physics has provided a panoply of powerful diagnostic tools that extend the experimental horizons of chemistry. Chemical theory has advanced to full partnership in the discipline, substantially aided by the revolutionary advances made by computer scientists. Molecular biology has made remarkable progress in its elucidation of life processes and has placed before chemistry challenging problems that require explication at the molecular level. Hence it is timely for a new assessment of the status of chemistry, the opportunities that can be seen ahead, and the resources needed to pursue them. This report presents that assessment.

Chemistry is a central science that provides fundamental understanding needed to deal with many of society's needs. It is a critical component in man's attempt to feed the world population, to tap new sources of energy, to clothe and house humankind, to provide renewable substitutes for dwindling or scarce materials, to improve health and conquer disease, to strengthen our national security, and to monitor and protect our environment. Basic research in chemistry will help future generations to cope with their evolving needs and unanticipated problems.

Because of this responsiveness to human needs, chemistry has become a crucial element in the nation's economic well-being. The U.S. Chemicals and Allied Products industry employs more than a million people, makes annual manufacturing shipments totalling about $175 billion, and, currently, displays a $12 billion positive international balance of trade, second highest of all commodity groups. Our competitiveness in a range of international markets depends upon maintaining our present position of leadership in the chemical sciences. There is no area of basic science that offers a more secure investment in the nation's future.

Finally, our culture embraces the premise that learning about ourselves and our environment is an ample basis for encouraging scientific inquiry. Chemistry contributes substantially to this cultural enrichment. For example, nothing preoccupies humans more than questions about the nature of life and how to preserve it. Because all life processes are manifestations of chemical changes, understanding chemical reactivity is a requisite foundation for our ultimate understanding of life. Thus, chemistry, along with biology, contributes to human knowledge in areas of universal philosophical significance.

Fortunately, we find ourselves in a time of special opportunity for advances on all these fronts. The opportunity derives from our developing ability to probe and understand the elemental steps of chemical change and, at the same time, to deal with extreme molecular complexity. Progress is epitomized by the striking fact that the number of new compounds continues to increase at a rate that is faster than exponential. Powerful instrumental techniques furnish a crucial dimension. They account for the recent acceleration of progress that now promises especially high return from the investment of additional resources in the field of chemistry.



FASTER THAN EXPONENTIAL GROWTH IN CHEMICAL KNOWLEDGE

It will be helpful to describe here the organization of this report. Following this introductory chapter, an Executive Summary of the report makes up Chapter II. Each of the three Chapters III, IV, and V begins with three sections, A, B, and C, that focus on chemistry's responses to society's needs. Several of these sections are introduced, in turn, by a one-page vignette that presents in nontechnical language a case history illustrating chemistry's usefulness. The section then describes recent important accomplishments and identifies potentialities for the future. The potentialities stem from intellectual opportunities and opening research frontiers that are described in a Section D, where the vocabulary must sometimes be pitched at a more technical level than that used elsewhere in the report. Most of the frontiers depend upon sophisticated and expensive instrumentation that is described in a Section E, which highlights trends in instrument capabilities that account for chemistry's accelerating progress. The trends are usually accompanied by escalation in cost caused by the increasing complexity and capability of the equipment; this escalation is quantitatively evaluated. Chapter VI addresses issues of manpower and education and concerns itself primarily with factors that determine the effectiveness of doctoral education. Then, Chapter VII assesses the resources needed if the United States is to maintain a position of international leadership in chemistry. The assessment finds current funding levels inadequate to secure the substantial societal benefits to be derived from such leadership.

The current federal investment in chemical research is still historically rooted in a funding pattern appropriate to a test-tube and Bunsen burner era, an era long since eclipsed. The sophistication of a modern chemistry laboratory requires a much more vigorous and sustained financial commitment of both capital and supporting services. The cost is miniscule when weighed against the potential returns. We must encourage a scientific field brimming with opportunities for discovery that will advance human knowledge and strengthen the underpinnings of a critical industry, and we must attract a substantial share of our brightest young scientists to this rewarding task. This report presents a program that can accomplish these goals.

CHAPTER II

Executive Summary

SOCIETAL BENEFITS FROM CHEMISTRY

Chemistry provides fundamental understandings needed to deal with many societal needs, including many that determine our quality of life and our economic strength.

New Processes

The U.S. chemical industry has a current $12 billion positive balance of trade. Continued competitiveness depends upon constant improvement of existing processes and introduction of new ones. Advances in chemical catalysis and synthesis will be key to maintaining our current position of world leadership. (See Section III-A.)

More Energy

Ninety-two percent of our present energy consumption is based upon chemical technologies; this will remain true well into the 21st century. However, new chemistry-based energy sources will have to be tapped. They will include low-grade fuels for which better control of chemical reactivity is needed so that we can protect the environment while providing energy at reasonable cost. (See Section III-B.)

New Materials

The next two decades will bring many changes in the materials we use, including the materials in which we are clothed, housed, and transported. Chemistry will play an increasingly vital role in this interdisciplinary field because advances will depend upon ability to tailor new substances, including polymers, to replace and outperform traditional or scarce materials. (See Section III-C.)

More Food

To increase world food supply, we need improvements in the production and preservation of food, soil conservation, and the use of photosynthesis. In collaboration with contiguous disciplines, chemistry plays a central role as we seek to clarify in detail the chemistry of biological life cycles. Once clarified they can be nurtured and controlled, while undesired side effects are avoided through chemical identification and synthesis of hormones, growth regulators, pheromones, self-defense structures, and nutrients. (See Section IV-A.)

Better Health

All life processes—birth, growth, reproduction, aging, mutation, death—are manifestations of chemical change. Chemistry is now poised to clarify such complex biological processes at the molecular level. Hence it is making important contributions to physiology and medicine through rational drug design and, then, through synthesis of new compounds that promote health and alleviate specific ailments such as atherosclerosis, hypertension, Parkinson's disease, cancer, and disorders of the central nervous and immune systems. (See Section IV-B.)

Biotechnologies

Remarkable progress made in recent years by molecular biologists and biochemists in genetic engineering has been built upon basic chemical principles that determine the chemical structures and functional relationships between molecules and supermolecules (proteins, DNA) within biological systems. Full realization of the potentialities of the projected new biotechnologies will increasingly depend upon molecular-level understandings. Chemists will be active collaborators in the progress toward this goal. (See Section IV-C.)

Better Environment

A major contemporary concern is protecting the environment in the face of increasing world population, urbanization, and rising standards of living. Effective strategies for safeguarding our surroundings require that we know what's there, where it came from, and what we can do about it. Chemistry lies at the heart of the answers to each of these questions: it can provide analytical techniques that give early warning of emerging problems, recognition of their origins, and access to alternative products and processes to ameliorate undesired impacts. (See Section V-A.)

Continued Economic Competitiveness

The value of U.S. chemical sales is near $175 billion, and we have a positive balance of trade. Preservation of our quality of life depends significantly upon maintaining this position of leadership. Our future competitiveness will be dependent upon staying in the vanguard as the frontiers of chemistry change and upon supplying to industry a stream of talented young scientists who have been working at these frontiers and using state-of-the-art instrumentation. (See Section V-B.)

Increased National Security

Key factors underlying national security are a healthy populace and a dynamic, productive economy. In both spheres, chemistry plays an essential role. In addition, the nation must be able to deter armed conflict. Again, chemistry is a vital contributor; it enters all areas of defense from propulsion, weapons materials, and classical munitions to the most advanced strategic concepts. (See Section V-C.)

INTELLECTUAL FRONTIERS IN CHEMISTRY

Fortunately, this is a time of intellectual ferment in chemistry deriving from our increasing ability to probe and understand the elemental steps of chemical change and, at the same time, to deal with molecular complexity. Powerful instrumental techniques are a crucial dimension. We can anticipate exciting discoveries on a number of frontiers of chemistry.

Chemical Kinetics

Over the next three decades, we will see advances in our understanding of chemical kinetics that will match those connected with molecular structures over the last three decades. Lasers by themselves have spectacularly expanded experimental horizons for chemists. They can now probe chemical reactions on a time scale that is short compared to the lifetime of any transient substances that can be said to possess a molecular identity. Elementary reactions can be dissected, first, through detailed control of energy content of reactants and, then, through discrimination of energy distribution and recoil geometry among the products. Pathways for energy movement between and within molecules can now be experimentally tracked and theoretically resolved. These new avenues of study will clarify the factors that govern temporal aspects of chemical change. (See Section III-D.)

Chemical Theory

Chemistry is on the verge of a renaissance because of emerging ability to fold experiment and theory together to design chemical structures with properties of choice. With today's computers, accurate calculations can clarify transient situations not readily accessible to experimental measurements, such as intermediate steps in combustion processes. In some cases benefitting from the power of computers, theoretical understandings are developing across chemistry, including dynamics of reactive collisions, electron transfer reactions in solution, and statistical mechanical descriptions of the liquid state. (See Section III-D.)

Catalysis

Developing insights fueled by an array of powerful instrumentation are now moving catalysis from an art to a science. It is now possible to "see" molecules as they react on catalytic surfaces. Metal-organic compounds with purposeful steric specificity and reactivity can be prepared. Organic molecules with predetermined surface conformations that simulate enzymatic architectures can be synthesized. Coherence is appearing that encompasses surface, solution, electrochemical, photochemical, and enzymatic catalysis. Fundamental advances in these various facets of catalysis are forthcoming that will have great economic and technological impact. (See Sections III-A, III-B, V-D.)

Materials

Modern experimental techniques and chemical principles now permit systematic chemical strategies for discovery and design of novel materials. Hence, chemists are increasingly joining and expanding the specialist communities concerned with glasses, ceramics, polymers, alloys, and refractory materials. Coming years will see entirely new structural materials, liquids with orientational regularity, self-organizing solids, organic and ionic conductors, acentric and refractory materials. Chemists will have a central position on the most dramatic frontier of materials science, the design of molecular-scale memory and electrical circuit devices. (See Sections III-C, V-B, V-D.)

Synthesis

Modern instrumental techniques greatly facilitate discovery and testing of new reaction pathways and synthetic strategies. Our accelerating progress, which extends from invention of new families of inorganic compounds to the synthesis of ever-more complex organic structures, is erasing the border between inorganic and organic chemistry. Reactivity control in metal-organic molecules can now be achieved through insightful choice of molecular appendages; new soluble catalysts will result. Molecules with metal atom clusters at their cores can be synthesized to link the chemistry of bulk metals to that of simple metal-organic compounds. This linkage relates the action of dissolved and surface catalysts. Organic molecules of biological complexity can be structurally identified and precisely replicated; this opens the way to tailored biological function. (See Sections III-D, IV-A, IV-B, IV-D.)

Life Processes

The recent striking advances in biology have exposed problems of revolutionary significance that require analysis in terms of molecular interactions. With its ability to deal with molecular complexity, chemistry can play its role in investigating and clarifying the molecular origins of biological processes.

Working hypotheses for biological functions can be tested through deliberate synthesis of tailored molecules: natural product analogs, chemotherapeutic agents, proteins deliberately altered to provide new functions, genetic inserts. This will move us closer to real understanding of the basic workings of life processes in response to the strongest of human preoccupations, the nature and preservation of life. (See Sections IV-B, IV-C, IV-D, V-B.)

Analytical Methods

Conceptual advances in detection, characterization, and quantification of chemical species are benefitting chemistry and contiguous sciences on many fronts. Incorporation of computers is a key factor. Analytical separations based on a variety of chromatographic techniques are essential elements of the rapid progress in identification and synthesis of natural products. Novel ionization methods extend mass spectrometry to biologic macromolecules and other nonvolatile solids. Surface analysis and electroanalytical methods are helping to clarify important aspects of catalysis. Remote spectroscopic and a variety of laser techniques are furnishing timely contributions to environmental monitoring and protection. (See Sections V-A, V-D.)

PRIORITY AREAS IN CHEMISTRY (See Ch. VII.)

The strength of American science has been built by allowing creative, working scientists to decide independently where the best prospects lie for acquiring significant new knowledge. Many of the most far-reaching developments, both in concept and application, have come from unexpected directions. Thus, to list priority areas carries the risk of closing off or quenching some adventurous new directions with potential yet to be recognized.

Even so, it makes sense to concentrate some resources in specially promising areas. This can be done if we regard our research support as an investment portfolio designed to achieve maximum gain. A significant part of this investment should be directed toward consensually recognized priority areas but with a flexibility that encourages evolution in these areas as new frontiers emerge. A second substantial element in this portfolio should be support of creative scientists who propose to explore new directions and new ideas. Finally, a third element must be provision of the instrumentation and the infrastructure needed to assure the cost effectiveness of the entire portfolio.

Where this balance will fall for each of the funding sources will vary. Industrial research will weight heavily the currently recognized priority frontiers. At the other extreme, NSF must encourage the new avenues from which tomorrow's priority lists will be drawn. The other mission agencies should structure their portfolios between those extremes. With such a balanced portfolio in mind, the following priority areas and identified with the intent to achieve the greatest intellectual and societal returns.

EXECUTIVE SUMMARY

Recommendation 1

Priority should be given to the following research frontiers:

- A. **Understanding Chemical Reactivity**
- B. **Chemical Catalysis**
- C. **Chemistry of Life Processes**
- D. **Chemistry Around Us**
- E. **Chemical Behavior Under Extreme Conditions**

Recommendation 1 should be implemented through initiatives sponsored by the relevant mission agencies, scaled by each agency in its own appropriate balance with its support of creative scientists expected to explore new directions and new ideas.

Initiative A. Understanding Chemical Reactivity

We propose an initiative to apply the full power of modern instrumental techniques and chemical theory to the clarification of factors that control the rates of reaction and to the development of new synthetic pathways for chemical change.

Principal objectives are to sustain international leadership for the United States at the major fundamental frontier of chemistry—control of the rates of chemical reactions—and to provide the basis for U.S. competitive advantage in development of new processes, new substances, and new materials.

Initiative B. Chemical Catalysis

We propose an initiative to apply the techniques of chemistry to obtain a molecular-level and coherent understanding of catalysis that encompasses heterogeneous, homogeneous, photo-, electro-, and artificial enzyme catalysis.

A principal objective here will be to provide the fundamental knowledge and creative manpower required for the United states to maintain competitive advantage in and to develop new catalysis-aided technologies.

Initiative C. Chemistry of Life Processes

We propose an initiative to develop and apply the techniques of chemistry to the solution of molecular-level problems in life processes and to develop young research scientists broadly competent in both chemistry and the biological sciences.

A principal objective of this initiative will be to accelerate the conversion of qualitative biological information into techniques and substances useful in biotechnologies, in human and animal medicine, and in agriculture.

Initiative D. Chemistry Around Us

We propose an initiative devoted to understanding the chemical make-up of our environment and the complex chemical processes that couple the atmosphere, *oceans, earth, and biosphere, with special reference to man's conscious and inadvertent disturbance of this global reactor. Analytical chemistry and reaction dynamics define the core of this initiative.*

Principal objectives of this initiative are to provide the basic chemical understandings needed to protect our environment and to extend detection of potentially hazardous substances well below toxicity bounds so that potential problems can be anticipated and ameliorated long before hazard levels are reached.

Initiative E. Chemical Behavior Under Extreme Conditions

We propose an initiative to explore chemical reactions under conditions far removed from normal ambient conditions. Chemical behaviors under extreme pressures, extreme temperatures, in gaseous "plasmas," and at temperatures near absolute zero provide critical tests of our basic understandings of chemical reactions and new routes toward discovery of new materials and new devices.

Principal objectives are to broaden our understanding of chemical change and to lead to new materials that will have application under extreme conditions of pressure, temperature, and exposure to specially challenging environments (e.g., fusion reactors, reentry vehicle heat shields, superconducting magnets).

EXPLOITING THE OPPORTUNITIES IN CHEMISTRY

The extent to which our nation will be able to benefit directly from these promising frontiers in chemistry is, in part, a matter of resources. This report shows that existing patterns of funding are anachronistic and inadequate. Average grant sizes are too small; for example, the average NSF grant will barely support the research activities of two or three students, while an active research group might range in size from six to sixteen (see Table VII-8 and the discussion preceding it). Furthermore, the grants do not provide support for the infrastructure needed to sustain the sophisticated scientific activities of today's chemistry (electronic, computer, and laboratory technicians, machinists and glass blowers, supplies). The inadequacy of support for "mid-cost" instrumentation (less than $1 million), both for shared use among several research groups and for specialized and dedicated use, requires painful trade-offs that tend to restrict capacity to fund new, young investigators entering chemistry. (See Figure, p. 302.) The instrumentation crisis is exacerbated because university chemistry departments are struggling to provide the operating and maintenance infrastructure needed to use this state-of-the-art equipment with maximum cost effectiveness. (See Tables VII-4 and VII-6.)

The listing of opportunities and potential rewards to society that will flow from them is impressive. That we cannot afford to lose these rewards is underscored by the economic importance of chemistry. Business and industry employ more doctoral chemists than the sum of those employed in the biological sciences, mathematics, physics, and astronomy combined (see Appendix Table A-4). Yet we find that the average federal investment in the crucial human resource in chemistry is only one fifth as much per Ph.D. as in other comparably important disciplines (see Table VII-1). Without a more determined U.S. commitment to the chemical sciences, there is substantial likelihood that our leadership position will be preempted abroad.

Chemistry in Industry

The Chemistry and Allied Products industry invests heavily in its own in-house research. This report should be of value to the industry as it decides upon the amount and focus of its own research investment. In addition, U.S. industry has an interest in the health and direction of university-based fundamental research. Industrial progress and competitiveness also depend upon access to a reservoir of fundamental knowledge constantly replenished by university-based research and upon a stream of talented young scientists familiar with the latest chemical frontiers and instrumental techniques. Hence, industry furnishes direct support to university research. Though modest in total (about $10 million each to chemistry and chemical engineering in 1983), it is extremely important because it facilitates movement of new discoveries into new applications and influences university research agendas.

Recommendation 2

New mechanisms and new incentives should be sought for strengthening links between industrial and academic research.

Recommendation 3

Industry should increase its support for university fundamental research in the chemical sciences. Tax incentives to encourage such gains should be explored.

The Federal Role in Fundamental Research

Industry can engage in only a modest amount of the most fundamental and adventurous research because the time horizon for application is remote. Yet, this "high-risk" research offers the most far reaching benefits to society and the intellectual basis for technological competitiveness. It is an appropriate place for public investment.

This report displays an array of opening research frontiers rich in potential for societal benefit. In this setting, an examination of funding patterns in a variety of disciplines that depend upon sophisticated instrumentation reveals that the federal investment in chemistry is not adequate and will not bring to society the full benefits to be realized.

Recommendation 4

The federal investment in chemistry should be raised to be commensurate with the practical importance of chemistry both economic and societal, and with the outstanding intellectual opportunities it now offers.

Chemistry and the NSF Mission

Chemistry supported by the NSF is judged on its potential for adding to our understanding of nature. Since the most far-reaching technological changes tend to stem from unpredictable discoveries, the fundamental research supported by NSF is critical to this country's long-range technological future. The increasing dependence of our economy upon the health of our chemical industry coupled with the exciting intellectual opportunities in chemistry justify a considerably larger NSF support in all three of its crucial dimensions: shared instrumentation, dedicated instrumentation, and grant size. Such support is needed to assure a U.S. position of international leadership in the exploitation of the rich opportunities before us.

Recommendation 5

(a) NSF should begin a 3-year initiative to increase its support for chemistry by 25 percent per year for FY 1987, FY 1988, and FY 1989.

(b) The added increments should be directed toward increasing grant size, ensuring encouragement of young investigators, enhancing the shared instrumentation program, and increasing the amount directed toward dedicated instrumentation.

(c) NSF should build into its shared instrumentation program a federal capital investment averaging at 80 percent of instrument cost together with maintenance and operating costs for a 5-year period after purchase.

Chemistry and the Department of Energy Mission

For at least the next quarter century, 90 percent of our still growing energy use must come from chemical energy sources. At the same time, the quality and character of feedstocks will be changing in ways that challenge existing technologies and that make it harder to resolve society's concerns about environmental pollution. To meet these challenges, the Department of Energy currently invests in its Chemical Sciences Program only 5 percent and in its Biological Energy Research Program less than 1 percent of the total resources it directs toward 11 of its largest fundamental research programs. To assure our future access to abundant and clean sources of energy over the next three decades, DOE must make a much larger commitment to the chemical sciences. This commitment must engage more fully both the DOE National Laboratories and the larger chemistry community.

Recommendation 6

(a) The DOE should establish a major initiative in those areas of chemistry relevant to the energy technologies of the future.

(b) In an appropriate number of our National Laboratories, the defined mission should be reshaped to include a major focus on one or more of the chemistry areas crucial to energy technologies.

(c) University research programs in energy-relevant areas of chemistry should be raised to be commensurate with those in the National Laboratories.

(d) Incremental growth in these programs by a factor of about 2.5 will be needed to exploit the opportunities before them. For cost effectiveness, this growth should be uniformly spread over the next 5 years. A \$22 million incremental growth in the FY 1986 DOE chemistry budget would support an appropriate beginning.

Chemistry and the NIH Mission

Progress in both medicine and chemistry now makes it possible to interpret complex biological events at the molecular level. Because of the ubiquitous role of chemistry in human health, NIH provides substantial support to chemists engaged in research at the broad interface of physiology/medicine/chemistry. Chemistry research relevant to the NIH mission concentrates largely in the Institute for General Medicinal Sciences. Characteristically, the grants are modest in size, and the award success rates have fluctuated widely over the last decade.

Recommendation 7

(a) A fraction of any additional NIH funds in support of chemistry should be used to increase average grant size, including grants for young investigators and particularly for cross-disciplinary collaborative programs that link expertise in chemistry with that in other health-science disciplines.

(b) NIH should vigorously continue its attempts to stabilize its extramural grant program.

(c) NIH should maintain its extramural shared instrumentation program at a level approximately equal to that of NSF. The initial federal capital investment should include at least 80 percent of instrument cost, and maintenance and operating costs should be provided for 5 years after purchase.

Chemistry and the Department of Defense Mission

Chemistry plays a critical part in our national security. It not only strengthens our ability to deter and prevent armed conflict, it also contributes strongly to the health of the economy and to the maintenance of the technical manpower pool needed to develop and deploy our increasingly sophisticated defense technologies. In the longer view, our future national security, our international economic posture, and our technical manpower supply dictate DOD attention to fundamental chemical research, including that conducted at universities. Yet DOD support of fundamental research has grown very little over the last 5 years; its investment in university research does not fulfull DOD's desire to maintain our manpower pool while providing indirect influence on university research agendas toward promising chemistry areas key to our defense posture.

Recommendation 8

(a) The percentage of the DOD R&D budget directed to basic (6.1) research should be increased to restore the 1965 value of 5 percent.

(b) DOD support for university research in the chemical sciences should be raised to about 25 percent of the total federal support for basic research through real growth at 10 percent per year.

(c) Parallel growth should be provided to DOD in-house research programs of the 6.1 category in chemistry.

(d) Growth should concentrate attention on the special opportunities now offered through chemistry in the following broad research areas:

—Strategic and critical materials
—Fuels, propellants, and explosives
—Atmospheric phenomena
—Chemical and biological defense
—Nuclear power and nuclear weapons effects

(e) Interaction between DOD laboratories and universities should be encouraged and increased.

(f) DOD should continue its instrumentation program but with the addition of support for maintenance and operation.

(g) DOD should explore mechanisms to support new construction and renovation of university research facilities in particularly critical areas of chemistry.

EXECUTIVE SUMMARY

Chemistry and the Department of Agriculture Mission

The USDA devotes only a small portion of its R&D budget to chemistry research relevant to agriculture and animal health. But human needs are great, so we can ill afford to miss the relevant opportunities offered by chemistry.

Recommendation 9

The Department of Agriculture should initiate a substantial competitive grants program in chemistry with the aim of increasing extramural support of fundamental research in chemistry relevant to agriculture and animal health to an approximate par with the Department's intramural program.

Chemistry and the National Aeronautics and Space Administration Mission

The several initiatives proposed in this report present opportunities for improvement of the safety, range, and effectiveness of future space operations. Furthermore, NASA has unique capabilities for monitoring and mission-related concern about the changing chemical compositions of the troposphere and the stratosphere.

Recommendation 10

(a) The National Aeronautics and Space Administration should maintain a substantial commitment to the understanding of atmospheric chemistry.

(b) Increased attention should be directed toward special opportunities relevant to operations in space:

—high energy propellants,
—chemical behavior under extreme conditions;
—reaction kinetics and photochemistry under collision-free conditions.
—chemical aspects of life-sustenance in a closed system
—analytical methods for compositional monitoring in both the troposhere and the stratosphere

(c) NASA should more actively encourage academic chemists to address problems relevant to the NASA mission through competitive grants for fundamental research.

Chemistry in the Environmental Protection Agency

The EPA has significant R&D programs specifically and properly directed toward currently recognized environmental problems, and many of these programs involve chemistry. This agency assumes a much less active role in fundamental research relevant to its mission as epitomized by its tiny Exploratory Research program. This extramural program is now funded at $16M, less than 0.4 percent of the $4.25B EPA total. The EPA should follow the pattern of other federal mission agencies by defining those areas of research that underlie its mission goals and stimulating the expansion of knowledge in those areas through programs of fundamental research.

Recommendation 11

(a) EPA should increase the percentage of its R&D funds placed in its Exploratory Research program and its commitment to extramural fundamental research relevant to environmental problems of the future.

(b) EPA should encourage fundamental chemical research to clarify reaction pathways open to molecules, atoms, and ions of environmental interest.

(c) EPA should take a prominent role in support of long-range research in analytical chemistry with emphasis on extension of sensitivity limits, increase in detection selectivity, and exploration of new concepts.

(d) EPA should have as a conscious and publicized goal the detection of potentially undesired environmental constituents at concentration levels far below known or expected toxicity limits.

Conclusion

In the next two decades there will be dramatic changes in our basic understanding of chemical change and in our ability to marshal that understanding to accomplish deliberate purpose. The program presented here defines a leadership role for the United States as these advances are achieved. The rewards accompanying such leadership are commensurate with the prominent role of chemistry in addressing society's needs, in ameliorating problems of our technological age, and in sustaining our economic well-being. The costs of falling behind are not tolerable.

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SCIENCE

APPENDIX B

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Science serves its readers as a forum for the presentation and discussion of important issues related to the advancement of science, including the presentation of minority or conflicting points of view, rather than by publishing only material on which a consensus has been reached. Accordingly, all articles published in *Science*—including editorials, news and comment, and book reviews—are signed and reflect the individual views of the authors and not official points of view adopted by the AAAS or the institutions with which the authors are affiliated.

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Federal Support for Chemistry

During the past 2 years a substantial fraction of leading chemists has been associated with George Pimentel of Berkeley in the preparation of a National Research Council report detailing some of the progress, triumphs, and needs of their discipline. Much has happened in the two decades since the last NRC chemistry report. Chemistry retains a historic role as a crossroads of the sciences and a tremendous source of practical applications, but new capabilities and new tools have been added. A host of powerful analytical instruments has become available. Theoretical chemistry, in part based on the Schrödinger wave equation, is increasingly productive. Computer-produced three-dimensional displays of molecules are providing chemists with sharper insights into the geometries and interactions of molecules. Many of the approaches of physics are now being applied to obtain data on excited states of molecules and reaction mechanisms.

Last summer, before the choice of the new editor and the selection of John Brauman as Deputy Editor for Physical Sciences, the decision was made to mark the occasion of the issuance of the Pimentel Report with the publication of a number of articles in *Science*. They are being published in this issue, which anticipates slightly the appearance of the report. The articles sample some of the research activities that are now making chemistry a less empirical and far more powerful discipline than most of our readers encountered during their undergraduate and graduate days. A few examples from these articles are cited.

Molecular interactions (supramolecular chemistry) are the basis of the highly specific processes occurring in biology, such as substrate binding to an enzyme. Recognition of a substrate to a receptor requires both a geometrical fit and binding between the interacting species. In this issue a large number of different synthetic molecules are described that have cave-like structures which are capable of selective binding and hence separation of similar cations and anions. Other synthetic receptors may bind a substrate, effect a reaction on it, and release the products.

Three articles describe relatively new work on the dynamics of chemical reactions. Experimental tools include ion beams, mass spectroscopy, ion cyclotron resonance, and lasers. Use of tunable lasers permits selective excitation of particular states with photons ranging from infrared to deep ultraviolet. One laser may be used to excite a molecule to participate in a reaction, a second may be used to probe the reaction products. Since very short laser pulses can be used, the time between excitation and interrogation can be less than 10^{-8} seconds. A fundamental question to be investigated by short pulse lasers is the time required for the redistribution of intramolecular vibrational energy. That is, one excites a particular bond and then observes fluorescence from other vibrational states. For the C–H stretching motion the time required to transfer energy to other vibrational motions is of the order of 100 femtoseconds.

Heterogeneous catalysis plays a crucial role in the production of most industrial chemicals. Articles in this issue touch on efforts to achieve a better basic understanding of the mechanisms involved. Three factors that control surface catalysis are the atomic surface structure, an active overlayer on the surface, and the oxidation states of surface atoms. For example, the (111) crystal face of iron produces ammonia from N_2 and H_2 at 500 times the rate of the (110) face at 20 atmospheres and 450°C. In the hydrogenation of CO over rhodium the yields are predominantly CH_4. However, when Rh_2O_3 was used, oxygenated C_2 and C_3 compounds were produced, including ethanol, acetaldehyde, and propionaldehyde.

Important progess is being made in chemistry. In proportion to its contribution to the advancement of other sciences and its contributions to the economy, chemistry is the most underfunded of all the natural sciences. It is to be hoped that the efforts of Pimentel and his collaborators will be rewarded by a generosity that is merited.—**Philip H. Abelson**

APPENDIX C

CHEMISTRY AND THE NSF MISSION

The chemistry supported by NSF is judged mainly on its potential for adding to our understanding of nature rather than its presumed relevance to a practical outcome. Because the most far-reaching technological changes tend to stem from unexpected and unpredictable discoveries, the fundamental research supported by NSF is most critical to the long-range technological future of this country.

In NSF, the chemical sciences are supported primarily in three divisions: the Chemistry Division, the Materials Sciences Division, and the Chemical and Process Engineering Division. Chemists also participate to some extent in divisional programs in other NSF directorates: Biochemistry, Atmospheric Chemistry, Geochemistry, and Marine Chemistry. The Materials Sciences Division includes three chemical science-oriented programs: Solid State Chemistry, Polymers, and Metallurgy. Also included are the Materials Research Laboratories (the MRL Program), which block-fund groups of physicists, chemists, and engineers with relatively focussed and applied program goals. Table VII-3 shows the budgets for these programs over the years 1972 to 1984, both in current dollars and corrected with GNP deflators to constant, 1972 dollars.

Table VII-3 shows that over the decade 1972-1983, total NSF funding for the chemical sciences rose in real terms by about 40 percent; but this growth was concentrated in the materials sciences, which grew by 50 percent and in chemical engineering, which grew from a small base by about 90 percent. The Chemistry Division budget grew by 23 percent over the same period, during which costs of scientific instrumentation have increased much faster than inflation, and day-to-day dependence upon such instrumentation has become almost universal across chemistry. Over this same decade, our economy has depended more and more on the health of the chemical industry, as reflected in both the doubling of its contribution to the GNP and the growth of its positive trade balance. These factors, coupled with the exciting opportunities in chemistry, justify considerably larger NSF support.

To assess the extent to which incremental funds are needed, it is necessary to examine in detail the disposition that has been made of the available resources. This can be examined most clearly for the Chemistry Division budget and in terms of three funding dimensions: purchase of large instrumentation for shared use (either on a departmental or regional basis), purchases of expensive instrumentation for dedicated use, and the size of individual research grants. To

TABLE VII-3 NSF Funding of the Chemical Sciences, 1972-1984

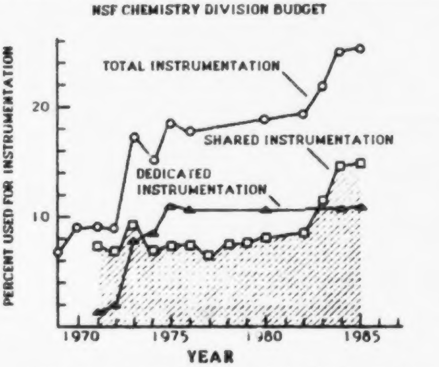
Year	Chemistry Division (in current-year dollars)	Materials Science Division[a]	Chemical Engineering	Chemistry Division (in constant 1972 dollars)	Materials Science Division[a]	Chemical Engineering
1972	24.5M	4.8M		24.5M	4.8M	
1973	25.1	5.0		24.0	4.8	
1974	26.6	5.1		23.7	4.6	
1975	32.7	5.8		26.5	4.7	
1976	34.7	8.2		26.3	6.2	
1977	40.2	9.8		28.6	7.0	
1978	43.1	11.3		28.7	7.5	
1979	45.2	11.5	13.0M	27.6	7.0	8.0M
1980	51.7	14.7	13.9	29.1	8.3	7.8
1981	57.6	14.9	16.7		7.6	8.6
1982	61.4	15.9	20.4	29.4	7.6	9.8
1983	67.6	16.2	22.6	30.8	7.4	10.3
1984 (est.)	80.0	19.5	26.6	33.2	8.1	11.1
1985 (request)	92.1	22.6	32.5	35.6	8.7	12.5
1985 (est.)[b]	87.8	21.5		33.8	8.3	

[a] This is the portion of the MRL budgets received by members of Chemistry and Chemical Engineering Departments, about 20 percent of the total. The remainder is directed to members of Physics and Engineering Departments who receive, respectively, about 45 percent and 35 percent of the total.

[b] After congressional action, as of January 1985.

begin, it is helpful to trace the history of funding by the Chemistry Division for these three elements.

Before 1970, instrumentation accounted for less than 7 percent of the Chemistry Division budget. It was then deliberately raised to about 9 percent for the years 1970 to 1972. Again a deliberate decision in 1973 led to another increase in the percent of the Chemistry Division budget spent for dedicated and shared instrumentation, this time to 17 percent. This percentage slowly rose to 18.6 percent by 1982. Now, in 1984 and 1985 it is about 25 percent.



STEADILY RISING INSTRUMENTATION COSTS (IN PERCENT OF CHEMISTRY DIVISION BUDGET)

Through much of this 15-year period, the amount expended for dedicated instrumentation has been essentially constant at about 10.5 percent. The major changes have been in response to the pressure for heavier investment in shared instrumentation. Taken together, shared and dedicated instrumentation have eaten away a larger and larger fraction of the Chemistry Division budget with the result that almost no real growth could be directed toward the other costs of performing research. Over the 11-year period 1972 to 1983, the budget less instrumentation rose only 5 percent (corrected for inflation).

The need to divert to instrumentation an increasingly larger fraction of the NSF Chemistry Division budget is but one of the symptoms of resources inadequate to the opportunities we must exploit and develop. To remedy this, we present an analysis of the needed level of resources in each of the major dimensions: shared instrumentation, dedicated instrumentation, and individual grant size. The analysis is based on the following four premises, the first of which is clearly established throughout this report.

—Chemistry is rich with opportunities for intellectual advances, for improvement of the quality of life, and for strengthening our economic competitiveness.

—We wish to assure a U.S. position of international leadership in the exploitation and development of these opportunities.

—We wish to attract to the chemical sciences an appropriate share of most promising young scientists to provide the talented manpower needed in this vital area.

—We wish to be sure that this enterprise engages the full national capability, as is appropriate to the national benefits to be derived.

Shared Instrumentation

The NSF has a proud heritage in its support of departmentally or regionally shared instrumentation. Unfortunately, through the 1970s, the NSF carried most of the load in supplying and maintaining such equipment in chemistry. However, current resources are quite insufficient. Many worthy requests must be declined, up to 50 percent cost-sharing might be required, and no allowance is made for ongoing maintenance. With the above four premises in mind, we offer here a systematic approach to estimating the need.

The NSF shared instrumentation program receives requests for a variety of instruments in the cost range of $200K to $800K. These requests reveal the instrumental techniques needed to conduct frontier research in chemistry. Table VII-4 lists eight examples of costly instrumentation commonly requested. No claim is made that every chemistry department needs every one of these instruments nor even a particular subset of them. We do assert, however, that a research university must maintain state-of-the-art capability for *some* of these instruments to remain front rank. The breadth of the research strength for a particular department will determine how many instruments would be needed to maintain international competitiveness. A large department with full breadth would require six state-of-the-art instruments in its "Departmental Instrument Inventory." With a somewhat narrower range of activity, three

TABLE VII-4 International Competitiveness in Shared Instrumentation

Departmental instrumentation menu	
(1) High-field NMR spectrometer	$750K
(1) Mass spectrometer	500K
(1) X-ray spectrometer	450K
(1) FTIR	200K
(1) Raman	200K
(1) ESR	200K
(1) Departmental computer	300K
(1) Array processor	250K
(8) Instruments	$2850K
Average capital cost per instrument	$355K
Cost share, NSF, 80%	$285K
Maintenance and operation at 20% capital cost year for 5 years	$355K
Total cost, NSF share per instrument	$640K

instruments might suffice. With a still sharper research focus, two instruments would probably keep a number of research faculty active at their research frontiers. Thus we begin this analysis by considering three "Departmental Instrument Inventory" levels—six, three, or two state-of-the-art instruments from the list in Table VII-4. At each level, the instruments must be replaced often enough to avoid obsolescence.

Experience in industrial research laboratories indicates that replacement time for the modern instrumentation under consideration averages about 6 years, a time determined by technical, not mechanical obsolescence. In other words, well before instrument-maintenance becomes a major problem, new instrument capabilities have become available that redefine the feasible research goals. On the average then, over a 6-year period, a department must have a reasonable chance to compete for continued access to the largest state-of-the-art capability for its Departmental Inventory.

The financing of such a program includes three elements: initial capital investment, cost-sharing policy, and ongoing costs of maintenance and operation. It is time to carry over from physics and astronomy the well-recognized principle that cost-effective use of sophisticated instrumentation requires ongoing support for maintenance and operation. Without this infrastructure support, such instrumentation is used neither at full efficiency nor full effectiveness. On the basis of studies on this issue, about 20 percent of the original capital investment for a 5-year period is needed. ***NSF should build into its shared instrumentation program annual operating and maintenance support (20 percent of capital investment) for a period of 5 years after purchase.***

Again we learn from physics and astronomy that cost-sharing by the institution becomes less and less viable as instrument costs continue to rise. Given the current financial stress in universities, we urge that ***the federal share of instrumentation capital investment should average at 80 percent.***

With these guiding recommendations on cost-sharing and infrastructure support, Table VII-4 shows that an average cost per shared instrument would require an NSF commitment of $640K.

Finally, we propose a deliberate approach to the question of how many U.S.

research universities can and ought to be in mind as NSF sponsors academic research in chemistry. There are 198 U.S. institutions that grant the Ph.D. degree in chemistry. The corresponding graduate faculty exceeds 4000, the number of postdoctorals is about 2800, and the number of full-time graduate (M.S. and Ph.D.) students exceeds 13,000. Of the 198 degree-granting institutions, we propose that at least 20 of them should be able to compete successfully for a Departmental Instrumentation Inventory of six major instruments. Such an institution could consider replacement of each of these instruments every 6 years, to average one per year. For a larger number of institutions—we propose 40—that competition might be successful every other year. For these, the Departmental Inventory could include three state-of-the-art instruments. For a next tier of 60 institutions, success would average 3 years, to maintain two modern instruments. These estimates—20 first-tier, 40 second-tier, and 60 third-tier institutions—can be seen to be modest in scale by comparing to the number of Max Planck Institutes in Germany. There are a dozen Max Planck Institutes in which chemistry is a central component. These Institutes might be considered analogous to our 20 first-tier research universities because they tend to be more richly endowed with instrumentation than the larger number of German universities also engaged in chemistry research. Scaling on the basis of total population, a dozen Institutes in Germany would correspond to about 40 competititive institutions in the United States (3.4 times higher). This shows that the level we propose is reasonable and needed if we wish to maintain international competitiveness. The cost of such a shared instrumentation program is shown in Table VII-5 and compared with the projected NSF Departmental Instrumentation budget for FY 1985. The NSF shared instrumentation budget falls far short of the need. ***The NSF Departmental Instrumentation budget for FY 1986 should be augmented by $25M.***

Dedicated Instrumentation

Much fundamental research today depends upon the sophisticated instrumentation just discussed but with such specialized application that shared use is quite impractical. However, the philosophy used above, based upon the same four premises, again furnishes an estimate of the resources needed to maintain U.S. leadership in a number of crucial specialty areas. This time an average cost per instrument is based upon a 15-instrument menu that weights some instruments more than others. Furthermore, it is assumed that no cost-sharing is required (as is

TABLE VII-5 Recommended NSF Program for Shared Instrumentation (Average Cost per Institution, $640K)

Number of Universities	Number of Instruments per Year	Cost per Year ($)
20 (on average)	1	12.8M
40 (on average)	1/2	12.8M
60 (on average)	1/3	12.8M
		38.4M
NSF FY 1985 departmental instrumental budget		13.5M
Needed increment		24.9M

currently customary for dedicated instruments) and that support for maintenance and operation (infrastructure support) is assumed for a 3-year period. The outcome is an average NSF investment of $350K per instrument (see Table VII-6).

The number of such instruments needed is reflected in the number of NSF grants made per year in those programs most dependent upon dedicated instruments. There is no point in making grants without providing the researcher his "tools of the trade." Four such programs are listed in Table VII-7 together with the planned FY 1985 budgetary allocation. To determine the instrumentation needs for international competitiveness, we assume that a reasonable fraction of the grants will be able to compete for one or two of these instruments every 6 years. We suggest that within a 6-year period, the top 10 percent of the grants might win two (different) instruments and that the next 20 percent would compete favorably for one instrument. As Table VII-7 shows, this implies that over a 6-year period, 268 instruments would be purchased, a rate of 45 instruments per year. This annual cost, $15.75M, exceeds by more than a factor of two the amount recently planned. ***The planned FY 1985 NSF support of dedicated instrumentation should be augmented by $9.6M.***

TABLE VII-6 International Competitiveness in Dedicated Instrumentation

A dedicated instrumentation menu	
(1) Picosecond spectrometer	$360K
(1) Molecular beam	250K
(2) FTIR	400K
(6) Lasers (Yag Doubled, Raman shifted)	540K
(1) High-resolution mass spectrometer	400K
(1) X-ray spectrometer	500K
(2) Dedicated computer	600K
(1) Array processor	250K
(15) Instruments	$3300K
Average capital cost per instrument	$220K
Cost share, NSF, 100%	$220K
Maintenance and operation at 20% capital cost/year for 3 years	$130K
Total cost, NSF share, per instrument	$350K

Grant Size

As indicated earlier, instrumentation has absorbed almost all the growth in the Chemistry Division budget for the last 15 years. Though the instrumentation needs are by no means met, the impact on grant size has become increasingly acute. The adverse effect of this sustained level funding (corrected for inflation) is revealed by the level of effort supportable by the amount of an average grant. For example, if we begin with the proposed FY 1985 Chemistry Division budget, $92.1M, and subtract the amount planned for Departmental Instrumentation ($13.5M) and the probable amount for dedicated instrumentation (estimated at 10.5 percent, $9.7M), the remainder, $68.7M, is available for individual grants. The planned number of grants, 918, implies an average grant size of $74.8K. Perhaps $30K will be extracted for institutional overhead and fringe benefits, which leaves only $45K for research personnel salary costs and research expenses. This amount will barely support one postdoctoral, one-and-one-half graduate students, and 1 or 2 months' summer salary for the principal investigator.

Table VII-8 presents a range of possible grant sizes based upon various levels of effort and a set of reasonable assumptions about stipends, allotments for services, and supplies and small equipment needs. Overhead and fringe benefit costs are computed at an average value, 67 percent.

The levels of effort A, B, and C proposed in Table VII-8 range from one postdoctoral student and six graduate students (level A) to one postdoctoral and two graduate students (level C). While a single grant at level A would not suffice for quite a number of our highly productive research groups, it defines a substantial research program. Level C, although a much smaller program, is still one with the vitality and continuity needed for effective fundamental research. Table VII-8 adds levels D and E in recognition that research is also actively pursued and should be encouraged at undergraduate institutions and the smaller graduate institutions as an important element of undergraduate education and an effective means of invigorating faculty.

TABLE VII-7 Recommended NSF Program for Dedicated Instrumentation (Average Cost per Instrument, $350K)

NSF Program	Planned No Grants FY 1985	Proposed FY 1985 Budget ($)
Chemical physics	180	14.8M
Chemical dynamics	180	17.0
Structural and thermochemistry	180	15.5
Analytical	130	11.0
TOTAL	670	58.3M

For international competitiveness

Top 10%, 2 instruments/six years 67.2 = 134 instruments

Next 20%, 1 instrument/six years 134.1 = 134 instruments

268 instruments

$$\frac{268\ \text{Instruments}}{6\ \text{years}} = 45\ \frac{\text{Instruments}}{\text{Year}}\quad 45\ \$350\text{K} = \$15.75\text{M}$$

Present NSF budget = (0.105) ($58.3M) 6.12M

(if held at 10.5% of program funds)

Needed increment $9.6 M

TABLE VII-8 Proposed NSF Chemistry Grant Sizes

	Level of effort									
	A		B		C		D		E	
Postdoc, 20K	1	20.0	1	20.0	1	20.0	1/2	10.0	—	—
Grad's, 9K	6	54.0	4	36.0	2	18.0	1/2	4.5	—	—
Faculty summer, 4K/mo	2 mo	8.0	2 mo	8.0	2 mo	8.0	2 mo	8.0	2 mo	8.0
Services, 3.5K	(7)	24.5	(5)	17.5	(4)	14.0	(2)	7.0	(1)	3.5
Supplies, 4.5K	(7)	31.5	(5)	22.5	(4)	18.0	(2)	9.0	(1)	4.5
Subtotal		138.0		104.0		78.0		38.5		16.0
Overhead fringe, 67%		92.5		69.7		52.3		25.8		10.7
Small instruments		8.0		6.0		4.0		2.0		2.0
Total	239K		180K		134K		66K		29K	

With these levels in mind, we can now estimate the number of grants at each level needed to implement research programs that would maintain this country's international competitiveness, supply the talented scientific manpower sought by our industrial and government laboratories, and contribute our share to the increase of human knowledge. Table VII-9 shows a model with which to judge the present NSF grant program in the Chemistry Division. The model is consistent with and supported by the arguments that accompany Table VII-5.

TABLE VII-9 NSF Grant Needs for International Competitiveness

Number of Universities	A	B	C	D	E	Total
20	160	100	40	—	—	300
40	60	120	160	—	—	340
60	10	20	30	60	—	120
Colleges	—	—	—	—	80	80
	230	240	230	60	80	840
Cost	$55.0M	$43.2M	$30.8M	$4.0M	$2.3M	$135.3M
For international competitiveness 840 grants						$135.3M
Present NSF Chemistry Division budget					$92.1M	
Less departmenal instrumentation					13.5	
Less dedicated instrumentation					6.1	
Present NSF chemistry division budget Less instrumentation						72.5M
Needed increment						$62.8M

This model would provide NSF support for 2830 graduate students, about 35 percent of those currently engaged in Ph.D. study, and 730 postdoctoral students, 26 percent of the number currently at this educational level. These percentages are reasonable when compared to the data of Table VII-2 showing that NSF provides 45 percent of the federal support for chemistry research performed in our universities and colleges. Of course, chemistry is supported elsewhere in NSF, which accounts for the remaining contribution NSF makes to the support of this essential science.

Thus the proposed model points to a need for much larger funding in support of individual grants, even if the number of grants is not increased. That outcome does not imply or advocate focussing resources at a small number of established research centers at the expense of others. It does imply and advocate open competition for individual grants within the peer review system, and it assumes that an award, once made, will be adequate to complete the proposed research. It implies less proposal writing, less need for multiple grants to sustain a viable program, and provision for supporting infrastructure at all grant sizes. The discussion uses a tiered model merely to indicate the scope of the national research effort that could and should be aggressively pursuing the opportunities presented in this report. It is not intended that NSF seek to establish such a tiered structure. Nevertheless, the tiered model dramatizes the fact that even with much larger funding for chemistry, the number of institutions that would be fully competitive on the international scene would be well within the aspirations and needs of this nation of 50 proud states.

The startling revelation of Table VII-9 is how far the proposed FY 1985 Chemistry Division budget falls short of these aspirations and needs. Table VII-10 combines this with the analyses of Tables VII-5 on shared instrumentation and Table VII-7 on dedicated instrumentation. The cumulative increment shows the magnitude of the discrepancy between needs for international competitiveness and present support levels. Such inadequate support translates directly into lost opportunities and, in the long run, into lost leadership in science and industry. The nation cannot afford these losses.

TABLE VII-10 NSF Chemistry Division Budget Incremental Needs for International Competitiveness in Today's Frontiers of Chemistry

	FY 1985 Request	Increment Needed	Total Need (in FY 1985 dollars)
Departmental instrumentation	$13.5M	$24.9M	$38.4M
Dedicated instrumentation	6.1	9.6	15.7
Grants	72.5	62.8	135.3
Total	$92.1M	$97.3	$189.4M

Table VII-10 shows that ***the NSF Chemistry Division budget should be doubled,*** after correction for inflation. For cost-effectiveness, ***it is recommended that the NSF begin a 3-year initiative to raise the NSF support for chemistry by 25 percent per year for FY 1987, FY 1988, and FY 1989. The added increment should be used for increasing grant size, ensuring encouragement of young investigators, enhancing the departmental and regional instrumentation program, and increasing the amount for dedicated instrumentation.***

Creativity Within NSF

The Chemistry Division in NSF has a laudable record of innovativeness and flexibility in its funding patterns. Its Young Investigator and Shared Instrumentation programs were responsive to encouragement by the 1965 predecessor to this report. More recently, it has experimented with new contractural mechanisms that cluster grants from a given institution, peer review based on "recent track record," one-time extensions based on creativity, and Regional Instrumentation Facilities. ***The Chemistry Division is encouraged to continue seeking new mechanisms of funding that help NSF fulfill its unique role of stimulating adventurous and innovative research with as little constraint on that research as possible.***

In the simplest analysis, NSF should try to support creative people in a fashion that permits them to be creative. This can be done within the peer review system by eliciting judgments from reviewers based as much on their evaluations of the investigator's research promise as on his or her research promises, as stated in the proposal. For established investigators considerable weight should be placed on originality evident in recent accomplishments. On this basis, perhaps 10 percent of the existing grants might be extended a few years without a new proposal (at the program officer's discretion). (This is now being done in NIH with the so-called "Javitz grants" within the Institute for the Neurosciences). Alternatively, especially creative programs ready for renewal might be supported for longer durations, such as 5 to 7 years.

The NSF should maintain its attention to the special needs of the new investigators whose continued entry into chemistry is essential to its long-range vitality. A current difficulty is the large "start-up" costs associated with initiation of research in almost any area of chemistry. A second problem is the time required for build-up of research productivity. Both require risk-taking that must be open to NSF program officers. Grant duration must be sufficient to avoid forcing young scientists into pedestrian research programs sure to lead to quick publications; 4- and 5-year grants should not be considered excessive. Multiyear grants should accommodate especially large, first-year "start-up" costs.

Finally, within bounds set by reasonable accountability, NSF should strive to minimize the number and length of proposals required for an active and productive investigator to obtain adequate support. The increase in grant size advocated here would immediately reduce both the number of proposals per investigator and the diversion of the research community in the operation of the peer review system. Increased grant duration would have the same salutory effects. Grants of less than 3-year's duration should be avoided, and 5-year grants should not be uncommon. Finally, the current NSF limit on proposal length—about 15 single-spaced pages for the proposal itself—should be enforced. Both program officers and reviewers should be encouraged to return single-investigator proposals that are excessive in length.

CHEMISTRY AND THE DEPARTMENT OF ENERGY MISSION

DOE support of the chemical sciences is embedded in a total R&D FY 1985 budget amounting to $5778M, which rose by 4.1 percent from the FY 1984 level. However, 44 percent of this is directed toward Defense R&D, which rose by 10.3 percent. When these R&D activities are subtracted, the non-Defense R&D total, $3245.9M, is found to fall slightly relative to FY 1984 (by .2 percent).

In another profile of the FY 1985 DOE R&D budget, two-thirds will be expended in the DOE National Laboratories, which, all together, saw their proposed collective budgets rise by 8.5 percent from 1984. By difference, the one-third expended outside the National Laboratories ($1889.8M) fell by 3.8 percent. A component of the difference is attributable to the concentration of the overall budget increase in Defense-related R&D, most of which is conducted in 4 or 5 of the 12 National Laboratories.

29 November 1985, Volume 230, Number 4729

SCIENCE

APPENDIX D

AMERICAN ASSOCIATION FOR
THE ADVANCEMENT OF SCIENCE

Science serves its readers as a forum for the presentation and discussion of important issues related to the advancement of science, including the presentation of minority or conflicting points of view, rather than by publishing only material on which a consensus has been reached. Accordingly, all articles published in *Science*—including editorials, news and comment, and book reviews—are signed and reflect the individual views of the authors and not official points of view adopted by the AAAS or the institutions with which the authors are affiliated.

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America's Ultimate Christmas Catalog

In this season when mailboxes overflow with catalogs featuring every imaginable Christmas gift, the National Academy of Sciences has sent us what should be one of the most exciting—*Opportunities in Chemistry*.* It is an impressive 350-page catalog of the gifts to society that the chemical sciences can provide if we will just fill out our national order blank.

Twenty years ago another NAS report†, usually called the "Westheimer" report, made a similar case for those times. Yet 9 months ago (22 February, page 847) in this space, Philip H. Abelson had to report, "In proportion to its contribution to the advancement of other sciences and its contributions to the economy, chemistry is the most underfunded of all the natural sciences." This new report (called the "Pimentel" report, for its chairman), after a masterful exposition of chemistry's advances and their potential applications, outlines specific and sensible shifts in federal budgets that would allow more effective exploitation of these advances for the national good. A determined effort is needed to ensure an adequate response this time, despite current budget stringencies.

The report underlines the great range of the chemical sciences. Examples in catalysis, optics, photochemistry, superconductors, biosynthesis, biopolymer structure, enzymology, spectroscopy, chromatography, molecular structure theory, computer graphics, stratospheric chemistry, geochemistry, and many more areas stress the interaction of chemistry with other sciences. The view of chemistry as the "central science" is not just a chauvinistic blanket worn by those of us with the word "chemistry" somewhere on our diplomas, but we have not always convinced others of that. This report should convince the careful reader.

It also lays to rest any notion that chemistry is a "mature" science, lacking in exciting research challenges. The many areas of practical importance are highlighted in each of the three technical chapters, and a section in each describes the "intellectual frontiers." Chemistry continues to offer major challenges to the "pure" researcher. At the same time it is the key to meeting many of the needs of society.

The chemical sciences have made many vital contributions to the welfare of mankind and have the potential for even greater contributions in the future. This is ably documented in the Pimentel report.

All who are concerned that science make its full contribution to national life should study this report and its recommendations. They will be convinced that we need full support of the chemical sciences by government, industry, and our educational institutions. Society will be repaid manyfold for such an investment of resources.—E. G. Jefferson, *Chairman of the Board, E. I. du Pont de Nemours & Company, Wilmington, Delaware 19898*

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*Committee to Survey Opportunities in the Chemical Sciences, *Opportunities in Chemistry* (National Academy Press, Washington, D.C., 1985).
†Committee for the Survey of Chemistry, *Chemistry: Opportunities and Needs* (National Research Council, Washington, D.C., 1965).

APPENDIX E

CHEMISTRY is a central science
that responds to societal needs.

It is critical in Man's attempt to...
feed the world's population

Whipping a Wicked Weed

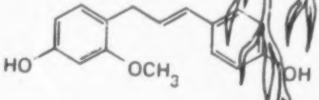
The plant *Striga asiatica* is one of the most devastating destroyers of grain crops in the world. This wicked weed restricts the food supply of more than 400 million people in Asia and Africa. It is a parasite that nourishes itself by latching onto and draining the vitality of a nearby grain plant. The results are stunted grain, a meager harvest, and hungry people.

Basic research on *Striga asiatica* by chemists and biologists has revealed one of the plant world's incredible host-parasite adaptations. The parasite seed lies in wait until it detects the proximity of the host plant by using an uncanny chemical radar. The give-away is provided by specific chemical compounds exuded by the host. *Striga asiatica* can recognize the exuded compounds and use them to trigger its own growth cycle. Then the parasite has an independent growth period of 4 days, during which it must locate the nearby host.

Researchers trying to solve the mystery of this recognition system faced formidable obstacles; they were seeking unknown, complex molecules produced only in tiny amounts. But, by extending the sensitivity of the most modern instruments, chemists have been able to deduce the chemical structures of these host-recognition substances, even though the agricultural scientist could accumulate the active chemicals in amounts no larger than a few bits of dust (a few micrograms). One method used, nuclear magnetic resonance (NMR), depends upon the fact that the nuclei of many atoms have magnetic fields that respond measurably to the presence of other such nuclei nearby. Thus precise NMR measurements reveal molecular geometries, even of ornate molecules. A second, equally sophisticated approach is high-resolution mass spectrometry. In a high vacuum, molecules are given an electric charge, then accelerated with a known energy. By measuring the velocities at which these molecules and fragments from them are traveling (or their curved paths in magnetic fields), chemists can measure the masses and decide the atomic groupings present. These are critical clues to the molecular identities.

Now, the complex host-recognition (xenogistic) substances have been identified and their detailed structures are known. With this information in hand, we may be able to beat this wicked weed at its own game. Chemists can now synthesize the substances and give agricultural scientists enough material for field tests designed to trick the parasite into beginning its 4-day growth cycle. It will die out never having found its host. A few days later, grain can be planted safely.

With this success for guidance, similar host-parasite relationships are being sought—and found—here in the United States. In addition to grains, bean crops have similar parasite enemies. Thus in collaboration with agricultural and biological scientists, chemists play a crucial role in our efforts to increase the world's food supply and eliminate hunger.



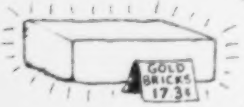
CHEMISTRY is a central science
that responds to societal needs.

It is critical in Man's attempt to...
discover new processes

Beauty Is Only Skin Deep

Ever think of going into the gold-brick business? Just take a big hunk of gold and a hacksaw and you've got a good-looking brick with a nice heft. Unfortunately, one such brick and you're talking $140-150,000! There's no room for mark-up. But suppose you get an ordinary brick (wholesale in South Jersey, 17¢!) and just coat the surface with gold—the cost will come down a lot. And you'll have a beautiful brick—well, at least "skin-deep."

So how much would such a surface coating cost? For openers, put a one-atom-thick layer of gold atoms over the entire surface of the brick. Let's see, 2 inches by 4 inches by 8 inches—gold at $320 an ounce—one atom thick—that'll be . . . 0.3¢ worth of gold. Wow! There, we've got an attractive product at a total material cost of 17.3¢ (not including packaging).



That's pretty impressive. It means that the outermost layer (the surface) of a $150,000 piece of gold involves so few atoms that they would cost less than a cent. Yet that miniscule fraction of atoms on the surface of a piece of metal controls the chemistry of that piece. For instance, these surface atoms are the ones that determine whether the metal surface acts as a catalyst or not. And catalysts account, one way or another, for about 20 percent of our gross national product.

So what is a catalyst? It's a chemical substance that speeds up a chemical reaction without itself getting into the act (i.e., it is not consumed while doing its thing). A solid catalyst merely furnishes its surface as a meeting place for gaseous molecules. For instance, when a molecule of methanol lands on a rhodium catalyst surface, it usually sticks for a while (becomes adsorbed). Now, if a carbon monoxide molecule happens to arrive, zingo, it reacts with an adsorbed methanol molecule and they leave the surface as acetic acid. When methanol and carbon monoxide meet in the gas phase, they won't even give each other the time of day. But because of the special environment provided by that thin layer of surface atoms on the rhodium catalyst, methanol and carbon monoxide react so rapidly that 500,000 tons of commercial acetic acid are made every year this way! This kind of speed-up might be anywhere from a thousand-fold to a million-fold when things are working.

Because of such successes, chemists care a lot about how these catalytic gold bricks do their job. What actually happens to that thin layer of adsorbed molecules as they come and go on a catalytic metal surface? Unfortunately, that's where the skin-deep principle works against us. If there isn't much on the surface, there isn't much to see.

But nowadays, we have several powerful instruments with which we can learn about the special properties of the skin of a metal. These instruments also let us watch molecules as they lodge on the surfaces of catalysts like platinum and rhodium and many others. We can see how the molecules are chemically changed by the metallic skin to make them more reactive when a suitable reaction partner comes along. So chemists are beginning to understand how to design these catalytic gold bricks to do whatever we want. Right now, every gallon of your gasoline began as a bunch of molecules sure to make your engine knock and then some chemist catalytically converted them into other molecules that make your engine purr. But now we are looking ahead to new energy feedstocks with more sulfur and metallic contaminants that will require much better catalysts so that we can keep your engine purring and the air clean at the same time. We'll do it by learning how those catalytic gold bricks work so we can tailor them to our needs. This is a case where skin-deep beauty really pays off!

CHEMISTRY is a central science
that responds to societal needs.

It is critical in Man's attempt to...
tap new sources of energy

A Lithium-Powered Heart

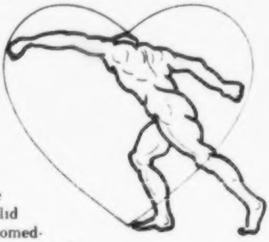
The cardiac pacemaker is a modern miracle of science that many of us take for granted--but not a person who owns one! These pacemakers operate on battery power, and the demands put on the tiny batteries that generate it are awesome! They must start the human machine every morning *without fail*, and the human lights and radio are running all the time. Yet many, many people are adding healthy years to life by betting on the chemical reactions that occur in these batteries to generate—day in, day out—the electric current that drives their pacemakers.

These batteries have special requirements because they must be implanted in a human body. They must be rugged and leakproof, have long life and minimal weight, and, of course, they must be nontoxic. The first batteries used in pacemakers had a lifespan of only 2 years, and the periodic operations required for replacement meant additional risk and stress for the patient.

Chemists began to tackle this problem, and research efforts in electrochemistry uncovered lithium metal, a new substance with the potential to give long life to batteries. Unfortunately, lithium is highly reactive—it burns in air and reacts with water to produce flammable hydrogen gas. If lithium were to be used, it would be necessary to discover new, nonaqueous electrolyte systems.

Electrolytes are substances that dissolve in water to form conducting solutions. They dissolve to produce ions, particles carrying electrical charge. The movement of these charges carries the current as the battery's chemistry releases its stored energy. Conventional batteries that draw on the chemical energy of zinc and mercuric oxide depend upon aqueous electrolytes. So the problem for the chemists to solve was defined—to design a battery that would operate without water.

Extensive investigations into new solvents and new materials for use in high energy, long-life batteries eventually led to the discovery of a solid electrolyte for use with lithium metal. The solid electrolyte is iodine, and the lithium-iodine battery was born for biomedical applications. These revolutionary batteries are currently in use, and they have an impressive lifespan of 10 years! The benefits to those who must depend upon cardiac pacemakers are incalculable.



The lithium-iodine battery is not the end of the story. It is a vast improvement over its predecessors and extremely useful in pacemakers, but it has a lower power than would be optimum for other uses. On the horizon is the need for new, higher-power batteries for use in other implantable organs like artificial kidneys and hearts. But further electrochemical research will undoubtedly provide the answer. It has in the past, and it will again.

CHEMISTRY is a central science
that responds to societal needs.

It is critical in Man's attempt to...
develop new materials

Stone Age, Iron Age, Polymer Age

There was a time when everything from arrowheads to armchairs was made from stones. Other features of those good old days were air-conditioned caves and charbroiled saber-toothed tiger steaks (if you caught him instead of the other way around). Fortunately, this age ended when someone discovered how to reduce iron oxide to metallic iron using coke (carbon) as the reducing agent. That all happened several thousand years ago, so the caveperson chemist who got the patent rights to the iron age wasn't educated at MIT or the University of Chicago. But this chemical discovery profoundly changed the way people lived. It led to all sorts of new products like swords and plowshares and the inner-spring mattress. Can you imagine how those stone-agers would have reacted the first time they put on a suit of armor, or went up the Eiffel Tower, or took the train to Chattanooga? Well, brace yourself, because chemists are at it again! This time, we're about to enter the Polymer Age.

You may think we're already there, with your polyester shirt, polyethylene milk bottle, and polyvinylchloride suitcase. We walk on polypropylene carpets, sit on polystyrene furniture, ride on polyisoprene tires, and feed our personal computers a steady diet of polyvinylacetate floppy disks. In just the last 40 years, the volume of polymers produced in the United States has grown 100-fold and, since 1980, actually exceeds the volume of iron we produce. But the best is yet to come.

The structural materials with which we have been building bridges since even before the one to Brooklyn, and automobiles since the Model T, would seem to be the last stronghold of the iron age (pun intended). Would anyone dare to suggest that polymers could compete on this sacred ground? Well, no one perhaps except chemists. Right now, there's talk of an all-plastic automobile, and you're already flying in commercial airliners with substantial structural elements made of composite polymers. One of these, poly(para-phenylene terephthalamide), has a tensile strength slightly higher than that of steel. But where this polymer really scores is in applications where the strength-to-weight ratio matters a lot, as it does in airplanes. Even with its cumbersome name, this polymer has a strength-to-weight ratio six-fold higher than steel! To appreciate this advantage, you should know that a 1-pound reduction in the structural weight of an airplane reduces its take-off weight by 10 pounds (counting the fuel to lift the pound and the fuel to lift the extra fuel). No wonder this polymer, under the trade name Kevlar®, is used to build tail sections for the biggest airliners. Oh, and bullet-proof vests, too.

So what about this all-plastic automobile? Of course, weight reduction is the name of the game in trying to build fuel-efficient cars. Already there are automobile driveshafts made of polymers strengthened with stiff fibers, and similar composites are used for leaf springs (oops, there goes the inner-spring mattress!). Right now, U.S. cars contain about 500 pounds of plastics if you count, as well, the rubber and paint and sealants and lubricants and upholstery.

But what about the engine and the electrical system? What will we do about these in this allegedly all-polymer car? Gee, I'm glad you asked. . . .

CHEMISTRY is a central science that responds to societal needs.

It is critical in Man's attempt to...

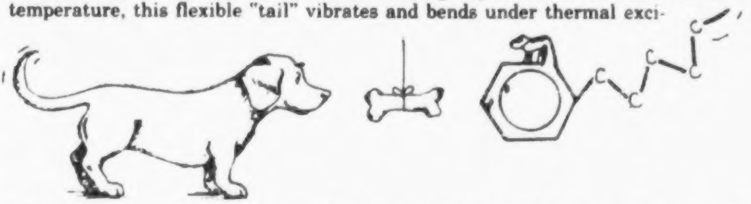
discover new processes

The Time It Takes to Wag a Tail

When your pet dog sniffs a bone, instantly his tail begins to wag. But it must take *some* time for the northernmost canine extremity to send the news all the way south where enthusiasm can be registered! How long does it take for that delicious aroma to lead to the happy response at the other end? Chemists are now asking the questions much like this about their pet molecules! If one end of a molecule is excited, how long does it take for the other end to share in the excitement? That time may determine whether the excitation will result in a chemical reaction in the part of the molecule where the energy was injected, somewhere else, or nowhere at all.

For the canine experiment, we need a hungry dog, a quick hand with the bone, and a quick eye to read the stopwatch. For molecules, it's much harder. Only within the last few years has it been possible to measure the rate of energy movement within a molecule. But chemists now have pulsed lasers giving bursts of light with durations as short as a millionth of a millionth of a second (a "picosecond"). Comparing a chemical change that takes place in 1 picosecond to a 1-second tail-wag delay involves the same speed-up as a 10-second instant replay of all historical events since the pyramids were built.

The alkyl benzenes provide an example. Each of these molecules has a rigid benzene ring at one end and a flexible alkyl group at the other. At room temperature, this flexible "tail" vibrates and bends under thermal excitation. But to act like our hungry dog, the molecules must be cooled to cryogenic temperatures, while avoiding condensation. Supersonic jet expansion makes this possible. When a gas mixture flows through a jet nozzle into a high vacuum, the molecules can be cooled almost to absolute zero. An alkyl benzene molecule carried along in such a stream loses all its vibrational energy, thus relaxing the molecular tail. Then, the cold molecules intersect a brief pulse of light with color that is absorbed by the benzene ring. With careful "color-tuning," extra vibrational energy can be placed in the head without any vibrational excitation in the tail. Then we must watch the molecule to see how long it takes for the tail to wag. Fluorescence lets us do this.



When a molecule in a vacuum absorbs light, the only way it can get rid of the energy is to re-emit light. Such fluorescence can be recorded with a fast-response detection system to give a spectrum that carries a tell-tale pattern showing where the extra energy was at the instant the light was emitted. Those molecules that happen to emit right away after excitation show the molecular head vibrating and the tail still cold. Those that emit later have an emission spectrum that shows that the tail is wagging. In this way, we have learned that the time it takes for the alkyl benzene tail to begin to wag depends on how long the tail is. Surprisingly, the longer the alkyl, the faster the movement out of the ring. The result shows what determines energy flow within molecules (the "density of states"). Such information might one day clarify combustion and help us make fine chemicals out of coal.

CHEMISTRY is a central science
that responds to societal needs.

It is critical in Man's attempt to...
improve health and conquer disease

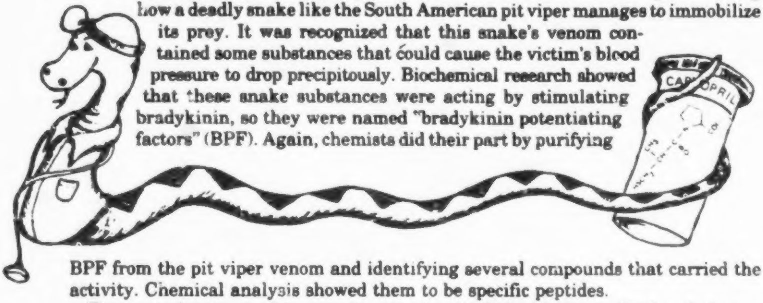
R_x-Snake Bite

High blood pressure, anyone? Maybe you'd like a dose of snake venom? Yes, it's true! Hypertension sufferers may find their future treatment coming from this unlikely source—and from sustained research in chemistry and physiology.

This story began 30 years ago when scientists discovered the chemical mechanism by which blood pressure is elevated in humans. Chemical techniques isolated two closely related substances, angiotensin I and angiotensin II. In the human body chemistry, II is produced from I with the help of a specific enzyme, "angiotensin-converting enzyme" (ACE). Though I has no physiologic effect, its reaction produced *angiotensin II*, the most potent blood pressure-elevating substance known. Thus I provides a reservoir from which II can be made as needed to maintain a normal blood pressure level, a conversion controlled by the enzyme ACE.

It is no surprise that there is also a substance provided by Nature to lower blood pressure—this substance is called *bradykinin*, which, along with angiotensin II, seems to complete the control mechanism. To raise pressure when it is too low, make some angiotensin II using ACE. To lower blood pressure when it is too high, a dash of bradykinin will do the trick.

During the 1960s, a group of Brazilian scientists were bent upon learning how a deadly snake like the South American pit viper manages to immobilize its prey. It was recognized that this snake's venom contained some substances that could cause the victim's blood pressure to drop precipitously. Biochemical research showed that these snake substances were acting by stimulating bradykinin, so they were named "bradykinin potentiating factors" (BPF). Again, chemists did their part by purifying BPF from the pit viper venom and identifying several compounds that carried the activity. Chemical analysis showed them to be specific peptides.



The next chapter in this story began when ACE had been purified and characterized. That opened the door to understanding how the snake venom BPF did its work. Some of the peptides in BPF block ACE to interfere with the production of angiotensin II. Then, as a bit of a surprise, it was discovered that ACE derived part of its control function from an ability to inactivate bradykinin. Realizing this, the canny pit viper provides some peptides in its venom to protect bradykinin from inactivation! Thus these BPF peptides deprive the body of its ability to use ACE, either to raise blood pressure by producing angiotensin II or to moderate the lowering action of its own control substance, bradykinin.

With this understanding, teams of biologists and chemists recently began a systematic attack on hypertension, one of the most insidious causes of death in our stressful world. They synthesized a series of peptides modeled on those found in snake venom but designed for therapeutic use. Success came with the synthesis of the compound captopril. It acts as an ACE inhibitor, and clinical trials have amply demonstrated its ability to lower abnormally high blood pressure. No wonder that the medical profession has great expectations for ACE enzyme inhibitors in the treatment of our hypertensive population.

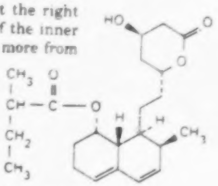
CHEMISTRY is a central science
that responds to societal needs.

It is critical in Man's attempt to...
improve health and conquer disease

A Pac-Man for Cholesterol

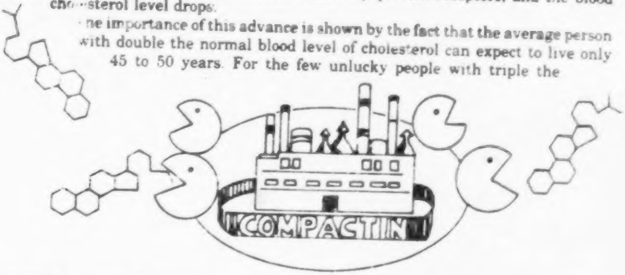
Since the 1960s we've known that high levels of cholesterol correlate with heart ailments, the major cause of death in the United States. What we need is a Pac-Man to chomp up the cholesterol in the blood and reduce "hardening" of the arteries that carry blood from the heart (atherosclerosis). Now a lowly fungus—not unlike the famous mold, penicillium—may have shown us one.

A normally functioning human cell uses a dual system for meeting its cholesterol needs. First, the cell has its own factory to manufacture cholesterol. In addition, the cell's exterior has a number of lipoprotein receptors that can grab onto cholesterol-containing lipoproteins as they pass by in the bloodstream and pull them inside. The cell fixes the number of these Pac-Man-like receptors so that just the right amount of imported cholesterol is added to the factory-made product. If the inner cell cholesterol level falls too low, more receptors are added to extract more from the blood stream.



There's an idea! If the cell's cholesterol factory could be slowed down, would the cell produce more receptors to make up the difference from the blood stream supply? A chance to test this scenario came when a biochemist discovered that certain fungi produced something that inhibited cholesterol synthesis. Chemists joined in the plot, purified the effective compound, determined its structure, and named it COMPACTIN. Knowing this structure, chemists were able to synthesize close relatives of compactin that are even more potent. Chemical tests with these new chemicals indicate that the scheme works as planned. The inhibitor slows down the cellular cholesterol factory, the cell produces more lipoprotein receptors, and the blood cholesterol level drops.

The importance of this advance is shown by the fact that the average person with double the normal blood level of cholesterol can expect to live only 45 to 50 years. For the few unlucky people with triple the normal amount, life expectancy drops to 30 or 35 years. To complicate matters, 1 in 500 Americans has the genetic disease *familial hypercholesterolemia* (FH). Victims of FH don't produce enough receptors at their cell surfaces, so lipoproteins accumulate in the blood and eventually cause heart attacks. Thus clinical researchers are excited to find that the new cholesterol-inhibitors work with FH patients, bringing the blood levels of cholesterol all the way down to the normal level. Much research remains, but these moldy chemicals offer immediate hope to FH sufferers and, in the future, to all people with abnormally high blood cholesterol.



CHEMISTRY is a central science
that responds to societal needs.

It is critical in Man's attempt to . . .
feed the world's population

Jack and the Soybean Stalk

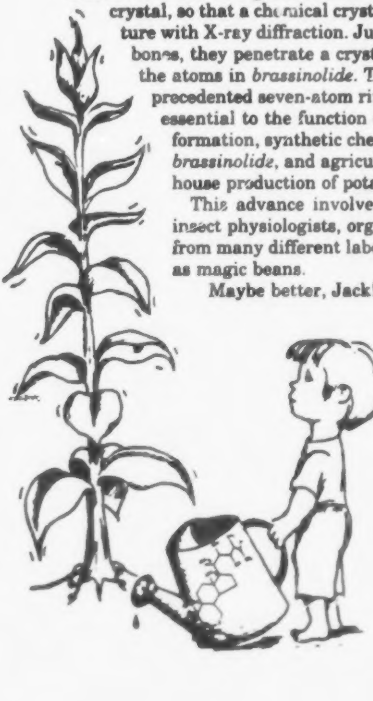
Perhaps a modern explanation for the amazing size of Jack's fairytale beanstalk can be found in *brassinolide*. This remarkable chemical is an extremely effective plant hormone that can double the growth of food plants, by both cell elongation and cell division. Only recently have chemists been able to isolate, identify, and then synthesize this valuable substance so that it can be used to increase the world's food supply.

Plant hormones have already revolutionized agriculture. They allow us to coerce cotton plants to release their cotton balls at harvest time, command fruit trees to cling to their fruit, induce Christmas trees to keep their needles, and order stored potatoes not to sprout. *Brassinolide* now can add to this list, and it is active in quantities of less than one-billionth of an ounce!

Chemists play a crucial role along the long and arduous research road from discovery to use of a new plant hormone. For example, *brassinolide* is found in minute quantities in the pollen of the rape plant (*Brassica rapus* L.). To isolate enough chemical to study, researchers laboriously collected pollen brushed off the legs of bees who had been cavorting in the rape plants. From 500 pounds of pollen so gathered, chemists were able to extract only 15 milligrams of *brassinolide*, an amount as small as a grain of sand. From this they were able to grow a single tiny crystal, so that a chemical crystallographer could analyze the molecular structure with X-ray diffraction. Just as X-rays penetrate an arm to reveal broken bones, they penetrate a crystal and reveal the geometrical arrangement of the atoms in *brassinolide*. The chemists were surprised to discover an unprecedented seven-atom ring within the molecule, a feature that must be essential to the function of this beneficial compound. With this key information, synthetic chemists have now made several close relatives of *brassinolide*, and agricultural scientists are evaluating them in greenhouse production of potatoes, soybeans, and other vegetables.

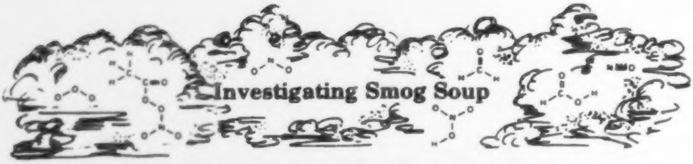
This advance involved the knowhow and interaction of plant and insect physiologists, organic chemists, and chemical crystallographers from many different laboratories. It shows that mental effort is as good as magic beans.

Maybe better, Jack!



CHEMISTRY is a central science
that responds to societal needs.

It is critical in Man's attempt to...
monitor and protect our environment



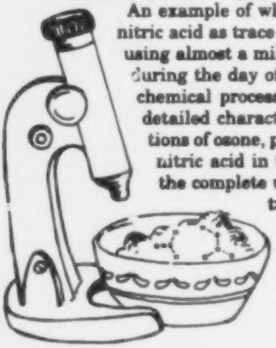
Investigating Smog Soup

Air pollution is a visible reminder of the price we sometimes pay for progress. Emissions from thousands of sources pour into the atmosphere a myriad of molecules that react and re-react to form a "smog soup." We are already aware of some of the potential dangers of leaving these processes unstudied and unchecked: respiratory ailments, acid rain, and the greenhouse effect. Surprisingly, you and I are the principal culprits in generating much of this unpleasant brew—everytime we start our cars or switch on our air conditioning or central heating! Transportation, heating, cooling, and lighting account for about two-thirds of U.S. energy use, almost all derived from combustion of petroleum and coal.

Pinpointing cause and effect relationships begins, inevitably, with the identification and measurement of what is up there, tiny molecules at parts-per-billion concentrations in the mixing bowl of the sky. Finding out what substances are there, how they are reacting, where they came from, and what can be done about them are all matters of chemistry. The first two questions require accurate analysis of trace pollutants. Physical and analytical chemists have successfully applied to such detective work their most sensitive techniques. An example is the *Fourier Transform Infrared Spectrometer*. This sophisticated device can look through a mile or so of city air and identify all the chemical substances present and tell us their concentrations down to the parts-per-billion level. Recognizing a substance at such a low concentration is comparable to asking a machine to recognize you in a crowd at a rock concert attended by the entire U.S. population.

How does this superb device work? "Infrared" means light just beyond the red end of the rainbow visible to the human eye. Hence infrared light is invisible, though we can tell it is there by the warmth felt under an infrared lamp. But molecules can "see" infrared light. Every polyatomic molecule absorbs infrared "colors" that are uniquely characteristic of its molecular structure. Thus each molecular substance has an infrared absorption "fingerprint"—different from any other substance. By examining these fingerprints, chemists can identify the molecules that are present.

An example of what can be done is the measurement of formaldehyde and nitric acid as trace constituents in Los Angeles smog. Unequivocal detection, using almost a mile-long path through the polluted air, revealed the growth during the day of these two bad actors and tied their production to photochemical processes initiated by sunlight. Continuing experiments led to detailed characterization of the simultaneous and interacting concentrations of ozone, peroxyacetyl nitrate (PAN), formic acid, formaldehyde, and nitric acid in the atmosphere. These detections removed an obstacle to the complete understanding of how unburned gasoline and oxides of nitrogen leaving our exhaust pipe end up as eye and lung irritants in the atmosphere. This advance doesn't eliminate smog soup, but it is a big step toward that desirable end.



CHEMISTRY is a central science
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It is critical in Man's attempt to . . .
monitor and protect our environment

Libraries into Space

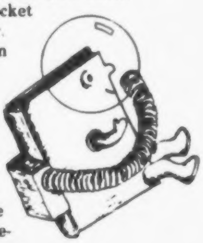
Unbelievable though it sounds, we may have to place whole libraries in a spacelike environment over the next decade! This strange proposal is not made because our orbiting astronauts need more reading material, but because if we don't do that or something similar, most of our books won't be around very long for the rest of us to read. An alarming and little known problem faces mankind today—the vast majority of books, those printed since the 1850s, are relentlessly yellowing and crumbling to dust. The library at the University of California at Berkeley alone stands to lose 60,000 books and periodicals per year to decomposition. This is not because of air pollution; the source of the destruction lies in the very paper on which the books are printed. Now, some clever chemists have discovered that, surprisingly, a trip into an environment similar to space provides at least one solution to this vexing problem.

Papermaking processes used since the 1850s universally employ an alumrosin sizing to keep ink from "feathering" or spreading on the paper. Slowly, this papermaker's alum—aluminum sulfate—combines with moisture in the pages and in the air to form sulfuric acid. This aggressive substance, in turn, facilitates attack on the cellulose fibers in the paper, breaking them into smaller and smaller fragments and, ultimately, to dust. Between 75 and 95 percent of the deterioration in "modern" paper is caused by such acid attack.

In recent years, chemists have developed a number of acid-neutralizing processes for books. One of these, developed in the Library of Congress research laboratory, suggests that the chemical diethyl zinc may be ideal for the job. Diethyl zinc is a gas, so its molecules can easily permeate even a *closed* book. Once inside, the substance deacidifies each book and then looks ahead to the future by leaving an alkaline residue of zinc oxy-carbonate. This residue, uniformly distributed throughout the paper fibers, protects the book from any future acid attack.

Ironically, this life-saving agent, diethyl zinc, bursts into flame on contact with air and explodes when it touches water. How does a chemist work with a compound that cannot be exposed to air or water? In a deep space environment, of course. A suitable location was found at NASA's Goddard Flight Center, where 5,000 books from the Library of Congress took a simulated flight, not on a rocket into space, but in a laboratory space-simulating vacuum chamber.

First, the books were thoroughly dried by warming under vacuum for about 3 days. Then, with all oxygen removed from the chamber, gaseous diethyl zinc was introduced and allowed to diffuse into the books. As the neutralizing reaction proceeds, harmless ethane gas is produced and pumped away. Then the protective zinc oxy-carbonate is formed. The results have been extremely promising, and, as the technology is perfected, libraries across the nation will be looking to install huge deacidification facilities. These countermeasures, coupled with the new "alkaline reserve" papers now used in modern printing, promise that the precious heritage of the world's libraries, including the enormous Library of Congress, will be preserved for future generations to enjoy, and profit from, just as we do today.



Mr. **Walgren**. Thank you very much, Dr. Gray. I appreciate that.

Dr. Smelser.

STATEMENT OF DR. NEIL J. SMELSER, PROFESSOR, DEPARTMENT OF SOCIOLOGY, UNIVERSITY OF CALIFORNIA AT BERKELEY

Dr. **Smelser**. Chairman Walgren, I am professor of sociology at the University of California-Berkeley, and I am going to be serving as the chairman of the academic senate of the whole university system next year. I ask your sympathy for that.

More relevant to this meeting, I have been a member for 6 years of the Committee on Basic Research in the Behavioral and Social Sciences of the National Research Council. I am currently cochair with Duncan Luce. We are preparing a 10-year outlook that will be parallel to the chemistry report and others that have been coming along, and our scheduled submission date for that is this coming summer, so we are moving well along.

I am very pleased to be back here once again. I was here some 5 months ago and testified, along with Duncan Luce and with Herbert Simon, on some exciting directions that were emerging in our own survey of the behavioral and social sciences. I will not summarize that. That is in your record and available to indicate the lines of our thinking as they have been progressing.

We are further along now, and while we haven't got the report on paper yet, it's coming along and our thinking has crystallized sufficiently well that I believe that the committee's work will be reflected in my own commentary on the fiscal year 1987 NSF budget with respect to the behavioral and social sciences. I will give you a little bit of history of the funding of behavioral and social sciences in the National Science Foundation. I would like to then say a bit about the two budgets and, third, I would like to say what I believe is missing from the 1987 fiscal year budget.

Over the past decade the history of funding for the behavioral and social sciences appears to have been more volatile and responsive to budgetary vicissitudes than other areas of support. For the Division of Behavioral and Neural Sciences and the Division of Social and Economic Science, if you look at it in graphical form—and I have provided you with a graph—it gives you a kind of rollercoaster effect of how the behavioral and social sciences are treated, beginning fairly well in the late seventies, then swooping down to a very low point, and then beginning a slight climb but very gradual, after bottoming out.

Well, I think we all know what the effect of rollercoasters is on our stomachs, and I think this has rather had that effect. In our 1982 report we affirmed that for research to be cumulative there really had to be a kind of steadiness about it—not that it is immune to change, but it cannot have this up-and-down, rollercoaster, feast-or-famine kind of quality about it. And in 1976 Professor Simon's report indicated that these divisions' budgets were quite small to begin with, so a number of high-quality proposals simply could not be supported.

Yet those programs over the years, combined with this roller-coaster effect, have actually diminished. If you think of 1985-equivalent dollars, the level has diminished in real dollars from $96 million in 1976 to $73 million in 1985, and that is a significant drop in the overall NSF percentage, falling from 7.8 percent of the budget to 5.7 percent in this year, so it has been a fluctuating and declining picture for those fields.

Furthermore, the number of grants has been fairly stable; that is to say, the number of grants given has not fallen but the average size of grants, if you add it up, has had to shrink, so that in 1985 grants averaged about 43 percent less in constant dollars than they did in 1978, for individual grants, and some of the programs and divisions are capping the level to which grants will be given.

As a result, the duration of grants awarded by those two divisions has fallen from 2.2 and 1.9 years, respectively, to 1.2 years for each division—a shortening and shrinking of grant size. So what happens is, the researchers must now submit proposals more often and get by with less resources, yet in my testimony and that of Professors Luce and Simon it is made abundantly clear that in the most exciting areas of development we are not making progress with a chalk and a board and a library carrel; that there are important and sophisticated new computational, experimental, and recording needs that cannot be met within the scope of the kinds of granting that cannot be met within the scope of the kinds of granting that are now dominant for our fields. These kinds of activity are simply falling by the wayside.

I would like to recall Professor Juster's testimony before this group in 1983, and he very eloquently pointed out how, over time, this kind of development cannot be continued without permanently warping, not just shrinking, the capacity of the affected fields, particularly by shutting down their ability to capitalize on new knowledge gains.

Moving on to the current requests, there are slight additional increments, for which I suppose one should be grateful in the current budgetary scene, but if you look at the general distribution, the same picture of puniness seems to emerge with respect to the behavioral and social sciences. If you look at the internal divisional spread, the BIO programs are in the $8 to $16 million range; BNS programs are in the $3 to $7 million range; IST—Informational Science and Technology—is in the $2.5 million range; Social and Economic Sciences, with the exception of economics, is in the $1.4 million range—that is to say, still very, very thin amounts.

The major thing that I would like to stress, in the few moments that I have to present this verbal testimony, is that we really do have an opportune moment for the behavioral and social sciences. That is to say, our committee is coming forward with a series of exciting new directions which we will be able to order in priority form for the National Science Foundation and other granting agencies to consider.

But if we look at the fiscal year 1987 budget, we do not find any room for any initiatives of that sort to be launched at this moment, so it seems to me that if this present kind of pattern that I have described to you continues, it will be likely to be something of a wheel-spinning operation that we have been going through; and in particular and most tragically, those most exciting and most promising lines of work are not going to be found or those initiatives are not going to be realized in that budget.

I spoke of a number of those lines, along with Professors Luce and Simon, last time, and I brought for the record several more that we have been—we have gotten into our vision. I will just mention them because they are summarized for you. I repeat the important lines of development: in the area of individual decision-making, particularly in the face of uncertainty as well as collective choice; the really dramatic advances that are occurring in the study of language —speaking, hearing; strides in the understanding basic demographic processes, particularly in the area of fertility; and, fourth, work in the history and contemporary significance of science and technology.

All of these are areas that are marching ahead. All of these are the areas that deserve support in some combination from the National Science Foundation and other funding agencies, but which do not seem to be possible to be sent forward with the vigor and support that we feel will be necessary.

The general line that we have found, in consulting with our colleagues around the country, is that the structure and level of funding in the National Science Foundation and more generally has come to the point where a variety of the most pressing needs are simply not being met in our fields, and I will just tick them off for you in conclusion.

First, equipment needs, including laboratory and computer equipment, which are often too costly to include in individual grants. I would like to point out that even the equipment survey mandated by Congress will not include equipment needs in the behavioral and social sciences. Furthermore, the computer needs of the behavioral and social sciences are not provided in the NSF's current supercomputer program.

Second, longitudinal studies, such as for discovering patterns of language acquisition, criminal careers, discovering migratory and fertility patterns in population cohorts, cannot be studied because of the shortness of duration of grants and their failure to be renewed.

Third, the support of collaborative, multiuser research installations, such as centers for the study of technological risk assessment.

Fourth, the support of major archiving efforts which are essential, for example, in tracing long-term trends in manpower and productivity in the history of science.

Fifth, collaborative research, including interdisciplinary work and collaboration with foreign scholars.

And, finally, consortia, summer training institutes in new methods and theoretical models, as well as other mechanisms for upgrading research skills. The usefulness of these has been clearly demonstrated but they have gradually waned over the years.

So, Mr. Chairman, I would just like to say somewhat sadly that the structure of funding at present is such that NSF support in these areas has become skewed away from a number of the vital aspects of work in the field. We cannot, I believe, over the longer haul mount major initiatives and really act as helmsmen to the research enterprise.

I would urge that, in its thinking, that this committee and the leadership of the National Science Foundation would take this message into account. It is not a simple request for augmentation. I believe that would be irresponsible. It is a matter of reconsidering the ways and the structure in which the funding is now carried out.

[The prepared statement of Dr. Smelser follows:]

Statement of Neil J. Smelser

University Professor of Sociology

University of California

Mr. Chairman and members of the Committee:

My name is Neil Smelser. I am a professor of sociology at the University of California, Berkeley. I am also serving as chair of the University-wide (nine campus) Academic Senate of the University of California in 1986-87. And of special pertinence to these hearings, I have for the past 6 years been a member of the National Research Council's Committee on Basic Research in the Behavioral and Social Sciences, serving as chair from 1982-84 and since then as co-chair with Professor R. Duncan Luce of Harvard. We are jointly overseeing the preparation of a ten-year outlook on research opportunities and priorities in the behavioral and social sciences.

It is a privilege to be here once again. Some five months ago, I testified before the Science Policy Task Force with Professors Luce and Herbert Simon of Carnegie-Mellon University. Each of us reviewed and sketched tentative implications of a selected set of areas where the basic research committee's work has unveiled promises of exciting and useful advances in knowledge.

Our committee's report, as expected, is substantially further along now, but it is not final and I cannot at this time give you the Committee's definitive conclusions or recommendations. However, the main direction of our thinking now seems well defined, and this has crystallized sufficiently my own thinking that my remarks on the 1987 NSF Budget Request are made with the prospect of the Committee's work firmly in mind. In particular, I note that FY 1987 will be the first budget year during which our report's published recommendations will be on the table -- a year in which, despite deficit-related concerns, the Administration wisely proposes that NSF spend 9.4% more on research than it is spending this year. So I consider this an opportune moment.

I propose first to outline the recent history of NSF programs in the behavioral and social sciences and characterize the choices that history frames for us now. Second, I would like to review the budget estimates and highlights of the FY 1986 Current Plan and FY 1987 Request to see what they contain for the behavioral and social sciences. And thirdly, I will tell you what I find missing from the 1987 Request.

The History. As you are well aware, support for behavioral and social sciences at the National Science Foundation has in the past decade or so been more volatile and responsive to various kinds of pressures than has other categories of research support. As a result, the funding trajectories of the Division of Behavioral and Neural Sciences (BNS) and the Division of Social and Economic Science (SES), as summarized in graphical, inflation-adjusted terms for the period 1978-1985, look rather like segments of a roller coaster, with a summit at the beginning, a steep slope, and a partial rise after bottoming out. These trajectories contrast sharply with the steady increases occurring over the same period for virtually all other parts of NSF's research.

The overall implications of a roller coaster budget need to be considered. As our basic research committee's 1982 report affirmed, a central desideratum for research support ought to be continuity--not immunity to change, but no violent change. And the recent history has not simply been a matter of slimming down. As Professor Simon's report concluded, these divisions' budgets were really quite lean to begin with, by every conventional measure, including the number of high-quality proposals that could not be supported. Yet the programs were so cut to the bone that even after several years of rising support, the 1985 level of $73 million contrasts with a 1978 level of $96 million in 1985-equivalent dollars. This is a significant drop, from 7.8% to 5.7% of the total NSF budget.

The actual number of grants made annually has been fairly stable. Whether by overall design or an accumulation of discrete decisions, the two Divisions seem to be serving about as many investigators as before. By inevitable arithmetic, the average size of grants has taken the brunt of the impact--a less serious impact for BNS, where the budget declined less and recovered more fully, than for SES, where the change is quite dramatic: in 1985, grants averaged about 43% less in constant dollars than they did in 1978. Some programs have even adopted fixed upper limits on grant size. For example, the current policy in the Program in History and Philosophy of Science places a cap of about $30,000 a year on individual grants, usually for a maximum of two years.

The average duration of grants awarded by BNS and SES has fallen from 2.2 and 1.9 years, respectively, to 1.2 years for both division. In order to sustain quality investigations, researchers must now submit proposals more often and get by with less resources. In particular, support in many programs is restricted to summer salary support and some part-time research assistance. Yet in my testimony with Professors Luce and Simon, in much other testimony before this Committee, and in numerous other documents, it is made abundantly clear that modern behavioral and social science research simply cannot be performed with chalk and board and a library carrel. While these are necessary beginnings and supplements, they are not sufficient. Sophisticated new computational, experimental, and recording equipment, mobility to field sites, facilities for collaboration and interchange are necessary as well, and the costs of these activities cannot be met within the grant sizes that are now typical.

The relevance of this history was stated by Thomas Juster in response to a question at these hearings in 1983: his comments are still right to the point. Basically, when the overall level of support for a scientific field is abruptly reduced due to external policy decisions rather than to trends arising within the research community itself, there is no way to avoid a jolting downturn in the overall productiveness of the enterprise. In the short term, the most equitable and administratively feasible way to absorb a sudden loss is by spreading it around to everyone involved. But this form of adjustment cannot be continued for long without permanently warping--not just shrinking--the capacity of the affected scientific field, particularly by shutting down its ability to capitalize on new opportunities for knowledge gains. Conversion of major support programs into small grant programs means that new state-of-the-art equipment cannot be purchased, collaborative efforts involving investigators at separate locations cannot be undertaken and, individual investigators cannot develop new research skills. In short, the innovative potential and excitement of the fields face the prospect of withering into a routine matter of refining existing knowledge rather than taking bold new steps.

The current request. A close look at the present budget request for the Directorate for Biological, Behavioral, and Social Sciences yields an interesting set of findings. First, the three Biotic/Bioscience divisions (BIO) are obviously larger at present than the BNS, SES, and Information Science and Technology (IST) divisions. This extends down to the Program Element level; each of the BIO Programs is in the $8-16 million range, while the BNS programs are each $3-7 million, IST is $2-5 million, and SES with the exception of economics is $1-4 million. If one considers that the number of potential researchers--represented, for example, by the total numbers of scientists employed in doctorate-granting universities and colleges--in the behavioral and social sciences is about the same as in the biological sciences, it is clear that the ability of the individual programs in BNS and especially SES to really have a significant steering effect on the directions of behavioral and social science research is quite different from the BIO programs.

Secondly, it is clear that the FY 1987 requests do not move in the direction of improving this imbalance between the BIO and the BNS/SES programs. (I would like to reserve comment on IST for a moment.) The SES and BNS divisions, smaller to begin with, are also slated to receive smaller increases than the BIO divisions in 1987, both absolutely and proportionately (4.6% and 7.0%, versus 8.4%, 8.6%, and 9.0%), so that, relatively speaking, the imbalance will get worse.

Obviously, this talk of balance within the Directorate and comparative leverage in the research community is only one factor to consider. Another possibility is that no major Foundation initiatives extend to these areas. But this is not the case. For example, in the ongoing commentary emphases, we find:

(a) biotechnology, which includes the assessment of technological risks, and which is considered by many neuroscientists as a key new method for investigating neuropeptides, among other topics;

(b) new resources for instrumentation, computation, and modelling, which are very much at the heart of work being done in cognitive science, microeconomic modelling, and other behavioral and social science fields;

(c) continuation of three large-scale data bases supported by SES--while additional resources for new data base collections were a casualty of the mid-year unspecified Congressional reduction; and

(d) teaching and learning of science and mathematics, which obviously extend into the BNS and SES programs.

In short, there is no obvious reason, in terms of ongoing emphases, why these divisions should be treated as they are in the FY 1987 request. So this brings me to my final point:

What is missing here? The answer is: room for substantial new initiatives of the sort that our ten-year outlook project is explicitly charged to identify.

Now obviously the budget does contain, in a few areas, some new initiatives, and I strongly support these. The most substantial initiative is in IST, where an across-the-board strengthening of that program by $2.65 million is proposed. But unfortunately, the IST division is shortly going to depart from the Directorate of Biological, Behavioral, and Social Sciences. I say "unfortunately" because there is a productive, growing interface between BNS, SES, and IST fields which will be harmed by this move. Note that two of our basic research committee's working groups were explicitly about "Information and Cognitive Science" and "Information and Decisionmaking."

The second significant initiative is in the neuroscience programs within BNS, where an additional $2.2 million is to be added. I strongly support this initiative. The sense of excitement among researchers in these fields over the advances possible with new instrumentation comes through with great conviction in our working group reports in this area.

Outside of these instances, there is no financial leverage for other new initiatives within the current request. What other initiatives do I have in mind? I will give you four examples, which are analyzed in greater detail in a written addendum that I would like to submit for the record. I present these illustrations from the standpoint of the Committee's general concerns and will not go into detail as to where these initiatives should be located within NSF or other Federal agencies. Let me clarify that while these are drawn from materials made available to the basic research committee, I am not naming or even forecasting the committee's specific recommendations at this point.

First, individual decisionmaking. In our prior testimony Professor Herbert Simon spoke on individual decisionmaking, and I spoke on collective choice. To refresh the memory of the Committee, I enclose a portion of Professor Simon's testimony in the addendum. In the study of decisionmaking, generally, our committee is determined to make this an important initiative. This seems particularly timely since the topic will be included in the research briefings to be held in June for the Office of Science and Technology Policy and the National Science Foundation.

Second, language. In the area of teaching and learning, we are beginning to recognize that mastery in science and mathematics involves a particular type of fluency. The processes of language acquisition are paradigmatic for all sorts of symbolic learning, and the bustle of new activity in neurolinguistics, automated speech synthesis and recognition, performance grammars, and the like has drawn intense but not necessarily long-lived private philanthropic interest. Bringing these fields to fruition may well need the kind of sustained, patient scientific investment that NSF is uniquely equipped to give.

Third, demographic change. These are subjects of great practical importance and lately, significant strides in data resources and theory. There has been a particular gap in support for methodological development, which NSF could be uniquely suited to fill. I have in mind support for developing and testing methods for estimating fertility in Third World nations. In addition, in developing linkages between government statistical-gathering agencies and the research community, NSF has begun to play a critical brokering function. There may be an opportunity here to generate real breakthroughs on the institutional as well as intellectual frontiers of the science.

Fourth, history of science. The modern research-based, high-technology organization, is a subject of intense interest within the behavioral and social sciences as well as in other scientific disciplines. Particularly important are information flows within and between organizations in which managerial choices involving occupational hazards are recurrent. Such occupations at risk involve steam boiler controllers, asbestos handlers, nuclear power plant operators, and even astronauts. This is an area in which NSF has truly unique connections with all the relevant fields, including the history and sociology of science and technology, the study of organizational behavior, markets and regulatory systems, small group decisionmaking, and of course the full range of NSF linkages to educational, scientific, small business, and corporate institutions.

I come now to the end of my argument. The Committee on Basic Research has worked to identify particular research priorities, which are substantive in the sense of clearly defined intellectual frontiers, and, often involve needed changes in the policy and practice of research. In light of the history I have sketched, many essential ingredients of research are being slighted or have fallen by the wayside. These include:

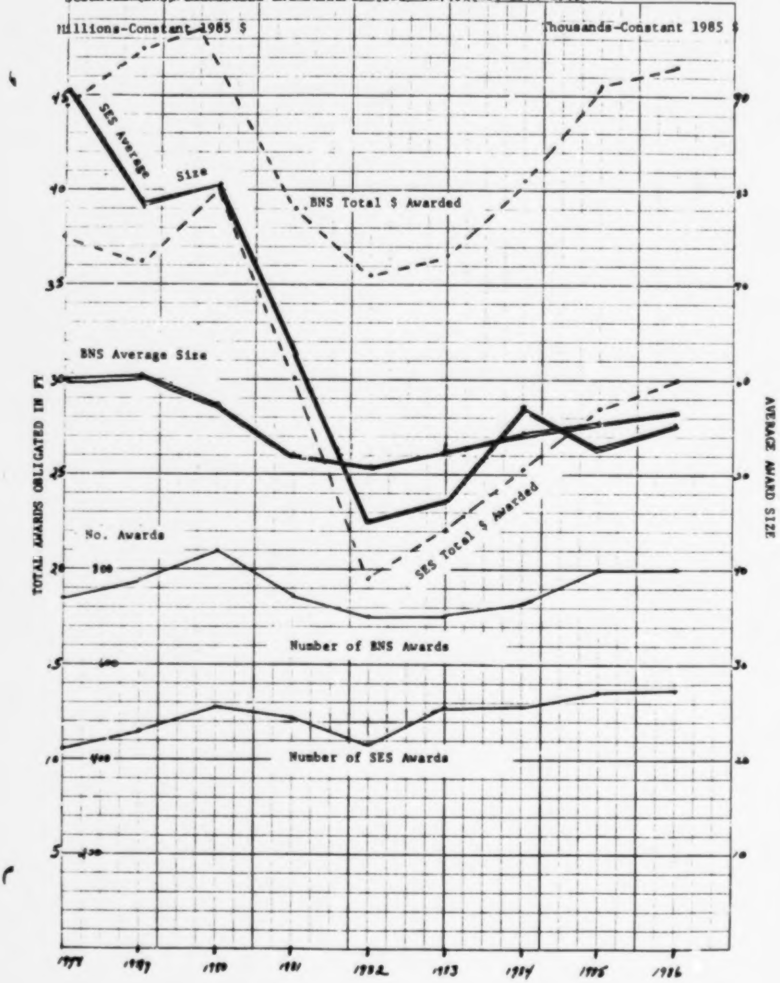
- Equipment needs, including laboratory and computer equipment, which are often too costly to include in individual grants. And I point out that even the equipment survey mandated by Congress will not include equipment needs in the behavioral and social sciences. Furthermore, the computer needs of the behavioral and social sciences are not provided for in NSF's current supercomputer program.

- Longitudinal studies, such as for the study of language acquisition, criminal careers, and for discovering migratory and fertility patterns in population cohorts--these are expensive and require sustenance over long periods of time.
- The support of collaborative, multi-user research installations, such as centers for the study of technological risk assessment.
- The support of major archiving efforts--such as those required for research on long-term trends in manpower and productivity in the history of science--which also call for sustained, multi-year efforts.
- Collaborative research, including interdisciplinary work and collaboration with foreign scholars.
- Consortia, summer training institutes in new methods and theoretical models, as well as other mechanisms for upgrading research skills, the usefulness of which have been clearly demonstrated but which have gradually waned over the years.

The structure of funding at present is such that NSF's support has become skewed away from a number of vital aspects of the research process in the behavioral and social sciences, including the ability to mount major initiatives and really act as helmsman to the research enterprise. There is some provision in the FY 87 budget request for responding to these kinds of problems with initiatives in neuroscience and in information science and technology, and I am very pleased to see this. But it is not nearly enough. I urge this committee, and the leadership of the National Science Foundation, to make explicit budgetary provisions that will enable the Directorate to respond fully to the kinds of challenges that our ten-year outlook was designed to - and will - set forth.

Thank you. I will be pleased to answer any questions.

Total Awards and Average Grant Sizes for The Behavioral and Neural Sciences (BNS) and Social and Economic (SES) Divisions, 1978-1986



ADDENDUM

SEVERAL AREAS OF ACTIVE RESEARCH

Individual decisionmaking. At the core of many social and behavioral phenomena lies the process of decisionmaking: of setting goals of action, finding or designing suitable courses of action, and choosing among alternative actions. One of the major accomplishments of the social sciences in the past half century has been to construct a carefully crafted formal theory of what it means to make decisions "rationally." One version of the theory asserts that the rational decisionmaker follows rules of choice that are mathematically equivalent to the notion of maximizing subjective expected utility, and it is thereby known as SEU theory.

The key assumptions of SEU theory are that the decisionmaker has consistent preferences among all possible futures (a utility function), estimates the probabilities of events in a consistent way (expectations take the form of subjective estimates of probabilities), and opts for strategies that dominate others (which is reflected as maximizing expected utility). The theory can be interpreted either as an intended description of human choice behavior or as a prescription of how people ought rationally to make their choices. As a prescription, it has found wide use in the tools of operations research (linear programming, dynamic programming, queuing theory) that are employed in modern industrial management. They are used not only in high-tech industries (e.g., for the blending of oil in refineries), but also in forest management and in the mixing of cattle feeds. Of course, before the SEU apparatus can be applied to real problems, the problems have to be redescribed in a highly simplified and approximate form. Nevertheless, the formalism has shown great practical value.

The SEU theory has great value, also, for conceptualizing the choice process, but as a description of human behavior, it falls far short of telling the truth, the whole truth, and nothing but the truth. As increasing research effort has been addressed, especially by psychologists, to discovering how people actually make choices, the inaccuracies and insufficiencies of SEU theory become increasingly clear. For example, the behavior of people in preparing for rare, but potentially very costly, events (e.g., buying flood insurance) cannot be explained even approximately by the SEU model. Today, the SEU theory, interpreted as a descriptive theory, serves largely as a framework on which the deviations of actual behavior from the model can be hung. And alternative theories are being developed that are based on less stringent rationality assumptions.

Since SEU theory lies at the core of modern economics (micro as well as macro) and statistical decision theory, finding an appropriate replacement for it stands high on the social science agenda. The problems with the theory do not lie in its logic--it is, in fact, a structure of the highest sophistication and mathematical rigor to which some of the best mathematicians, mathematical economists, and mathematical statisticians of our century have contributed. The central problem is that the standard version of the theory does not pay proper attention to the limits of human beings--of ourselves. It does not take into account how limited and inaccurate is the information we use in making decisions; how few of the potential options of choice we can discover or invent; and how limited is our ability to draw inferences and conclusions from the information that we do possess.

In short, the difficulty that has been found in decision theory can be traced to mankind's bounded rationality: to the limits of human information-gathering and thinking capacities in relation to the complex world that we face. These limits may be alleviated by the help we can get from computers, but even the biggest existing and prospective computers are puny in comparison with the world they are asked to analyze.

Simply recognizing human rationality as "bounded" does not provide a specific theory with predictive power that can replace the SEU theory in its present uses. The new theory will undoubtedly be truer to the facts than the one it replaces. As in the case of the theory of expectations (which is one part of it), it will call for very extensive empirical research, examining a wide range of human decisionmaking situations under a wide range of conditions.

Today, there is a considerable interdisciplinary "stirring" of research scientists in virtually all the social sciences, but especially psychology and economics, who see the need for building a more elaborate and realistic theory of decisionmaking and who are beginning to carry out the vast amount of experimentation and field research that will be required to reach this goal. Theorists, too, especially in the domain known as "the new institutional economics" are now busy constructing explanations of behavior in business organizations and of legal institutions that take account of more of the limitations on human rationality than have been considered in the past.

Language and speech. The human brain appears to be uniquely suited to acquire and use language. Chimpanzees and gorillas are able to learn less than one percent of the vocabulary of signs of a three-year-old child, and they cannot learn the grammatical rules already acquired by a two-year old child. By adulthood the monolingual human has a mental dictionary of more than 100,000 words, organized in complex structures.

New advances in the study of the acquisition of language suggest that there is a genetic proclivity toward the rapid learning of language, as there is in certain birds' capacity to acquire the songs of their species. Newborn children recognize and respond to phonetic distinctions that appear in languages other than the one normally spoken to them, sounds which have no functional significance for these infants. Further evidence for the biological distinctiveness of language is found in the fact that linguistic abilities may develop separately from other cognitive abilities. The literature reports cases of children who are retarded in many cognitive areas but nonetheless have complete mastery of grammatical structure. One young woman who has a non-verbal IQ only a little above 40, who draws at a preschool level, and who has an auditory verbal memory span of three units, nevertheless can produce syntactically complex sentences. Studies of users of sign languages reveal that these languages have the same abstract grammatical properties as spoken languages, but these properties are expressed in entirely distinctive ways. Deaf children or children with deaf parents who use sign language acquire that language without formal instruction, just as spoken language is acquired. Furthermore, studies of brain-damaged deaf show that the left cerebral hemisphere is dominant for sign language, just as it is for spoken language.

Interdisciplinary work by linguists, neurologists, and neuropsychologists has energized the new field of neurolinguistics, which is producing remarkable insights about the relations between brain and language. An important part of this work concerns local brain damage. Patients with damage only to their right hemisphere retain intact spoken and written language but show other cognitive deficiencies. Some patients with left hemisphere brain damage retain their ability to speak and understand language but develop reading and writing difficulties; others can read words with perfect pronunciation but cannot say what those words mean. A whole new technology of neuroimaging techniques, including magnetic resonance, permits much greater precision in locating different linguistic functions in the brain. Complex electrophysiological measures have also proven valuable in locating distinct patterns of electrical fields for parts of speech (nouns and verbs), content and function words, and in the mode of speech (spoken or signal), all of which suggests distinct cerebral locations and systems of control for these different linguistic activities.

In the past 25 years, collaboration between linguists, communication engineers, and computer scientists has led to increases in the understanding of the acoustic beses of speech and to new methods for analyzing acoustic speech signals. Advances in computer technology have made it possible to acquire and analyze in hours or days, rather than months or years, the large phonetic data bases needed to study the sound structure of language. However, the computers and their automated systems have far to go before they catch up with humans' ability to synthesize speech. It is formidably difficult to program computers to replicate the complex interaction among larynx, tongue, lips, and jaw, which blurs the simple sequences of phonemes and words into normal speech. It is also difficult to automate language processing when each uttered syllable or word varies in sound qualities according to its phonetic context, stress or emphasis, rate of speech, and dialect of the speaker. While great advances in the development of speech-recognition schemes have been made, the difficulties of the task are enormous. Even after 40 years of work, the best schemes can deal with only 5,000 words (as compared to the 14,000 known by a six-year-old or the more than 100,000 used by monolingual adults). Nevertheless, further developments are bound to improve our understanding of how the brain carries out the segmentation and analysis of linguistic systems, bringing closer the day when machines can help us learn to communicate directly across currently high barriers of different languages.

The study of language acquisition and use is genuinely interdisciplinary, calling for the articulation of insights and research results of many types of biological scientists, behavioral scientists, and students of language structure. Another feature of this study is that a multiplicity of different methods of research have contributed to our advanced understanding: longitudinal studies of language acquisition; the use of various brain-imaging techniques that localize regions of the brain used for different linguistic functions; the development of mathematical models and computer simulations of the rules underlying grammars; study of normal and brain-damaged patients; and the comparative study of different language groups. The challenges in the next decade include training and equipping future researchers in these diverse techniques.

Demographic change. Demography is a well-established tradition, a distinctive subfield on its own; but it also bridges sociology, economics, epidemiology, medicine, population biology, and anthropology. Demography involves study of the causes and consequences of changes in population size and composition. One major area of current research--and need--is fertility and its consequences.

A long-standing concern of social scientists, dating back to the eighteenth century, is the relationship between population change (especially growth) and human life in general (especially economic well-being). Many of the answers are not in, but some points are clear. On balance, large family size appears to be detrimental to the economic life-chances of families and their members, an effect that is seen across different baselines of economic status. The other side of this coin is that families that limit their size appear to benefit both as families and as individual family members on a variety of measures of well-being. However, the effects of family size on society as a whole, and the broad social and political consequences of population growth and decline are complicated and hedged with conditions that are not yet well understood.

In the coming decade research will continue to focus on determinants of fertility in developing countries, a topic fueled both by scientific curiosity and by policy concerns with rapid population growth. We need to understand the full social context of specific cases of fertility decline in developing countries. By social context we have in mind family economics, local and national administrative systems, cultural change, and deliberate governmental efforts aimed at reducing fertility. Theories abound: some stress that declines in fertility result from the elimination of "unwanted" childbearing; others emphasize structural factors that affect couples' "cost-benefit" thinking about having children; still others regard the decline of fertility as a response to the diffusion of Western ideas throughout the developing world. The recent work of the massive World Fertility Survey and the European Fertility Project has lent credence to the "diffusion" explanation, but the search for the right combination of factors underlying fertility decline is still open.

One of the impediments to understanding fertility in developing countries is the inadequate functioning of vital registration systems, so familiar and relatively complete as repositories of information on births, marriages, and deaths in most developed countries. In the relative absence of these, demographers have devised two indirect strategies for estimating levels and trends of fertility and mortality. One is to insert questions that yield such information on censuses or surveys. The second is to use mathematical models to extrapolate from known population features (especially age distribution and growth rates) and estimate levels of fertility and other unobserved variables from them. Such methods have proved valuable for understanding demographic trends not only in the developing countries but also the United States, where some surprisingly difficult-to-observe phenomena (such as the durations of marriages) have been built into models of estimation. Though the growth and testing of estimation methods has been rapid, it remains difficult to obtain methodological support for the development and testing of new estimation procedures.

Fertility research has also been carried out on the developed countries, but here it focuses on the very low levels--now below replacement levels in some countries of Western Europe. Overcoming infertility among childless couples is an area of concern. Private clinical efforts have experienced some success, but government efforts to enhance fertility through public incentive programs have not. Little is yet understood about the reasons for this failure, and this is perplexing because incentive aspects of welfare and tax programs are often asserted to be influential in keeping fertility rates high among the recipients of these programs. As often happens, the way to unlock one problem may be to locate the key to a second problem that is the flip side of the first. Another area of concern is the serious emerging consequences of low fertility and smaller incoming population cohorts. Among these consequences are the necessity of countries experiencing this pattern to rely on immigration to fill out their labor force and to face the social and economic consequences involved in accommodating these immigrant flows. Also, the new smaller cohorts face the costly prospect of supporting earlier, large cohorts who will be in dependent retirement status when the former are in their prime working ages.

Science. In recent decades sociological and historical studies have underscored the fact that science is not autonomous but is conditioned by and subject to forces in the wider society. Modern science originated in a complicated play of forces, some of them intellectual, others social, political, and economic. The requirements and organizations of industry, government, and philanthropy also shaped the scientific enterprise. And in the great industrial, governmental, and academic laboratories, science and engineering increasingly are conducted in groups organized around indispensable technologies.

One major theme in the recent social-scientific study of science concerns the sources of its growth and vitality. Spokesmen for science have argued frequently that the vitality of any branch of science is in large part dependent upon the manpower and economic resources invested. Careful quantitative cross-national study has thrown some doubt on such claims. One cross-national study of the personnel, funding, institutes, and productivity of physics in universities in the United States and Western Europe discovered that financial investment and manpower, calculated as fractions of national totals, were the same to within small fractional margins in France, Germany, Great Britain, and the United States. Productivity, however, as measured by numbers of papers published in the leading journals per dollar spent or person credentialed, differed greatly from a high for Germany to a low for the United States. If financial investment and manpower was not the determining factor, what was? Subsequent research points to the importance of hierarchy of authority in the scientific enterprise and suggests that scientific quality depends on who designs and controls institutions, particularly societies, journals, and elite centers of research. Comparative quantitative research is essential to generate, recheck, and give interpretive confidence to these kinds of findings.

Quantitative studies also provide data concerning growth rates in the respective sciences, rates of investment in research and training, and distribution of productivity among practitioners and institutions. They show that certain minority groups in the United States--Jewish Americans historically and later Asian Americans--participate in the technical enterprise to an extent greater than their weight in the population, while the converse has been true for other ethic minority groups and for women. Studies confirm that a disproportionately high volume of significant science across-the-board is produced by a relatively small fraction of the practitioners in a given area of work, suggesting that high-quality training or talent may rate a higher premium than sheer quantity of qualified researchers. Further depth to these quantitative results can be attained by means of traditional cultural and institutional studies. For example, uneven participation of women and different minority groups in American science requires reference to the cultures of the groups themselves, their histories and opportunities, and to the policies and practices of educational institutions.

Mr. **Walgren**. Thank you, Dr. Smelser. I appreciate that. Dr. Malone.

STATEMENT OF DR. THOMAS F. MALONE, DIRECTOR EMERITUS, HOLCOMB RESEARCH INSTITUTE, BUTLER UNIVERSITY

Dr. **Malone**. Thank you, Mr. Chairman.

As an alumnus of the Scientific Advisory Committee of george Miller of the 1960's, I am delighted to be back here in this room again and speak very strongly in support of the NSF initiative, special emphasis on global geosciences. It is leadership of the first order. In response to your invitation to be brief, I will say just a few words about what it means and then list five considerations which I believe are persuasive in support of this program.

The global geosciences follows this line of reasoning: that the interrelationship of the atmosphere, oceans, biosphere, and solid Earth is now recognized and the field is ripe for major advances. Recent technological developments of Earth-based and satellite observational instrumentation, the emergence of sophisticated modeling and computational methods, and the availability of high-speed, high-volume communications capabilities set the stage for investigations of the Earth as an integrated system of linked physical, chemical, and biological processes. Accordingly, the NSF is proposing an increment of $18 million against a base of $17 million for this program in which they and the Executive Office of the President have urged a special emphasis.

Now my first point is that this has strong support in both the national and the international scientific community. I pointed out in my testimony that in reflecting on advances since the IGY of 25 years ago, it was unanimously concluded that the time was ripe, and foreign scientists gathered at Ottawa in 1984 and had a symposium on this. There was unanimity among the scientists from all the major players in world science and many of the minor players that the time was indeed ripe, and we have had a whole series of workshops—one was here in Washington last week, one is going on in Montpellier, France—sharpening up this program, providing focus, and outlining how it should proceed.

It is a multidisciplinary program, and people like Lew Branscomb and Roland Schmitt have remarked that the most dramatic progress in developing the knowledge base responsive to national needs is likely to be made by those scientists who have matured in their own discipline and acquired a firsthand capability to deal with the tools and techniques of related disciplines. They both raised the question: Is the scientific establishment ready for this kind of preoccupation, and are the funding agencies also ready? I think the action of the NSF here indicates that the funding agencies are ready. The action of the scientific community also supports that, so I think the answer is positive to both questions.

I was interested in the discussion of education, of scientific literacy. A compelling case for a program of this kind is presented in the "Planet Earth" television series currently on the air, and if I have to leave early tonight, it is to rush back to Connecticut where we are conducting a telecourse for science teachers on this exciting program. It has proven to be extraordinarily stimulating to science teachers as a device for teaching science to people who are potentially scientific researchers of the future. The groundswell of public appreciation—speaking of scientific literacy—is simply astonishing in Connecticut.

Now with that strong scientific support and public awareness, the second point is the emergence of technology—the capacity to provide a global synoptic picture of the world in its entirety, to make detailed chemical measurements, to put that vast amount of data into high-speed computers for ready accessing by scientists, to build the models which relate the biota to the atmosphere, to the ocean, to the solid Earth—makes it possible to do today what could not have been done 25 years ago

A third point is that, in addition to the scientific excitement, I think this program represents a very special case of enlightened pragmatism. We are moving into an era when the number of people and human activity are both at a scale now to affect global change on a worldwide basis. The departure of your colleague to study acid rain, our concern with the greenhouse warming—these are manifestations. The problem of maintaining an adequate life support system in the face of population pressures is an imperative to build our knowledge base.

A couple of years ago 80 scientists from 20 countries gathered near Washington at the Wye Plantation and asked the question, "Can we stabilize human populations, improve people's quality of life, provide more food, save tropical forests and disappearing species, and protect the environment, and in ways that further other critical goals, both economic and humanitarian?" The answer was yes, but there are critical gaps in understanding, sufficiently broad sometimes to deter action. Now global geosciences is not going to answer all of these questions, but it is part of the base upon which these decisions will be made.

Finally, I would say that the structure of this program and the phasing of it is particularly impressive. It is an orderly evolution of ongoing programs. It is an interagency program, and if I had to make an editorial remark, I would say that after 20 years of advising Government agencies, never have I seen a program which I felt surpassed this one in interagency coordination and collaboration.

There are the four or five elements of the program—global tropospheric chemistry, global ocean flux, the world ocean circulation experiment, the tropical ocean global atmosphere experiment, the global ecosystem dynamics, which links the physical system and the biological system, the ocean ridge crest processes, which links the solid Earth, which is the final point of the plan. I have examined the phasing of this in great detail, as has my colleagues, and we think that it is doable and is one of the most important steps in the profound scientific and technological revolution that Lew Branscomb wrote about so eloquently in "The American Scientist."

Mr. Chairman, I guess in conclusion, so we can have time for questions, I would simply remark that this modest NSF effort is actually an imaginative yet prudent step toward fulfillment of the original charter of NSF—to coordinate and oversee our Nation's basic effort in research. I knew Alan Waterman very well and admired the course he set with wisdom, imagination, and circumspection, and I feel confident he would be very pleased with the thrust set before you today and the manner in which it is being advanced. I hope, in conclusion, Mr. Chairman, that your committee too will register its pleasure by authorizing this program.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Malone follows:]

STATEMENT BY
DR. THOMAS F. MALONE

I am pleased to speak in strong support of the NSF FY 87 Budget Request for Global Geosciences and to commend the Foundation for selecting this activity for special emphasis next fiscal year. There are several reasons for urging favorable action on this particular budget item by your committee, Mr. Chairman.

First, this felicitous focusing and consolidation of research support in closely related fields clearly reflects deliberations over the past several years within both our national scientific community (represented principally by the National Academy of Sciences) and the international scientific community (represented principally by the International Council of Scientific Unions -- ICSU). In 1982, Professor George Garland (Past President of the International Union of Geodesy and Geophysics), speaking at an ICSU symposium in Cambridge, England, commemorating the 25th Anniversary of the International Geophysical Year (IGY), remarked that many of the remaining mysteries about the processes affecting Planet Earth would be illuminated by studying the interactions between physical and biological processes. At a similar symposium during the annual meeting of the National Academy of Sciences in 1983, Dr. Herbert Friedman called for a bold, holistic venture in global research -- a multidisciplinary study to understand global changes in the terrestrial environment and its living systems. He argued persuasively that the real connections that link the geosphere and the biosphere are subtle, complex and often synergistic -- their study transcends the bounds of specialized, scientific disciplines and the scope of limited, national scientific endeavors. Subsequent workshops sponsored by the National Research Council in the United States and an international symposium in September, 1984, in Ottawa, Canada, during the 20th General Assembly of ICSU, explored in depth the timeliness of such an endeavor. Near unanimity was achieved on a positive response to the question of timeliness. National committees in several countries and an array of international working groups are busily engaged in developing programs, setting priorities, and addressing problems inherent in a multidisciplinary endeavor. The central thrust that appears to be emerging is

> to describe and understand quantitatively the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment it provides for life. the changes that are occurring in that system and the manner in which they are influenced by human actions.

As an aside, it may be noted that scientific statesmen such as Roland Schmitt and Lewis Branscomb, Chairman and Past Chairman of the National Science Board, respectively, have independently remarked that the most dramatic progress in developing the knowledge base responsive to national needs is likely to be made by those scientists who have matured in their own discipline and then mastered the tools and research techniques of related disciplines. Both have raised questions concerning the readiness of the scientific establishment and the financial support mechanisms to adapt to this new modus operandi. The Global Geosciences thrust of NSF, its strong support in the Executive Office of the President, and its deep roots in the scientific community suggest that we are, indeed, crossing the threshold of the fundamental and powerful intellectual revolution described so eloquently by Lewis Branscomb. This step represents enlightened pragmatism as well as intellectual excitement. We simply must come to understand processes such as the impact of El Nino on global weather, the so-called "greenhouse" warming, acid deposition, deforestation, desertification, earthquakes and volcanoes -- all of which have a profound impact on the public welfare and economic health of all nations, including our own! This thrust builds upon the explosion in our understanding of PLANET EARTH which has been so vividly communicated to the public -- and particularly to youngsters with a potential interest in science -- through the television series by that name now being seen on the Public Broadcasting System.

A second reason why this thrust is timely rests with the impressive accomplishments and promise of space technology, computers and advanced instrumentation. Remote sensing from satellites brings within reach the global, synoptic measurements that, validated by in situ observations, are required to bring the life-sustaining, physical, chemical and biological processes of Planet Earth under meaningful scientific scrutiny. The span of techniques for studying the dynamics of global ecosystems to techniques of tomographic imaging to study the dynamics of the earth's interior is large but is only a part of the continuum to be provided by space technology. To this capability one can add chemical techniques that measure substances in parts per trillion. The sheer volume of data that can be gathered would be daunting were it not for computational and communications capacity that make possible archiving, accessing and using those data to construct and test the mathematical models of the linked processes now ready for study.

A third reason for attaching importance to Global Geosciences is the growing realization that the world population and human activity have now reached a level at which anthropogenic change on a global scale is within sight -- if not already upon us. Climate change from radiatively active trace gases injected into the atmosphere, acid deposition, deforestation and desertification are examples which demand better understanding if we are to manage human activities in a manner consistent with maintaining the integrity of our global life support system. In a broad sense the financial support proposed for Global Geosciences is a vital down payment on an investment we need to make toward a positive approach to the FATE OF THE EARTH as we move into the 21st century.

This thought warrants some amplification. Earth is unique among the planets of the solar system in the fact that it is benign to living creatures. With ample sunshine, a moderate temperature, liquid water, and appropriate biogeochemical cycles, the physical and biological setting has been conducive to a thousand-fold increase in human population over the last 10,000 years. Estimates suggest that the population will likely double to 10 billion people over the next 100 years with 1.4 billion living in developed countries and 8.7 billion residing in presently less developed countries. The population in developing countries will almost inevitably increase by 2 billion during the next several decades.

These numbers pose challenges to adequate and equitable access to food, fibre, energy, human health, water, biologically productive soil, and other natural resources. This issue, and the overarching problem of resolving national differences by peaceful means, have been addressed at intergovernmental and nongovernmental conferences over recent years. The most recent — The World Resources Institute Conference, "Global Possible" — concluded that "We can stabilise human populations, improve people's quality of life, provide more food, save tropical forests and disappearing species, and protect the environment ... and in ways that further other critical goals, both economic and humanitarian" but that "...there are critical gaps in understanding, sometimes sufficiently broad to deter action." The research required to fill these gaps has intrinsic scientific interest as well as profound societal implications. The scope of the problems requires an international collaborative effort. The Global Geosciences Program is a welcome step toward putting in place that effort.

The tragic and deteriorating situation in Africa where the population of more than a half a billion people is losing the ability to feed itself is a portent of the kind of challenge that African leaders and the international community face over the remainder of this century and the beginning of the next one. But as Lester Brown and his colleagues have pointed out in "State of the World: 1986" these problems of a sustainable and secure society are "of human origin and can yield to human remedy." The Global Geosciences Program is a modest — but important — contribution to the search for that remedy.

Finally, I must say that I am favorably impressed with the structure and balance of the Global Sciences Program as a coherent and coordinated interdisciplinary undertaking and the effective manner in which it is integrated with related programs in NOAA, NASA, DOD, USGS and ONR. It is an orderly evolution, convergence and extension of ongoing programs. I have examined the proposed distribution of incremental funding among Global Ocean Climate, Global Tropospheric Chemistry, Global Ocean Flux, Global Ecosystem Dynamics, Ocean Ridge Crest Processes and the Solid Earth and, in my judgement, the relative emphasis accorded each is as nearly right as fallible human judgement can make it and reflects sound evaluation of the current stage of (1) planning, (2) instrumentation, (3) field programs and (4) analysis, interpretation and numerical modeling in each area of research. The projected efforts in each of these stages over the next decade were particularly useful. The growing importance of chemical and biological processes as the vital link among the domains of the atmosphere, oceans, biosphere and solid earth is reflected in the identification of Global Tropospheric Chemistry, Global Ocean Flux and Global Ecosystem Dynamics as integral elements of the program, while according to the Global Ocean Climate the support that fundamental base of the geosciences properly commands. The task of fostering a successful collaborative effort between biologists and physical scientists is not to be underestimated, but the experience last summer of bringing the two groups together in a workshop organized by the University Corporation for Atmospheric Research left me persuaded the the community of interest is sufficiently strong to overcome the disparities in traditional research methodology and in the scale of phenomenon under investigation. A workshop of solid earth scientists to discuss Global Change last week here in Washington, sponsored by ICSU, was an indication of the interest of that community in the approach NSF is advancing. Down the road there is a formidable task of designing an effective, internationally accessible, data-management and information system. The UNIDATA program at NCAR is a sort of prototype of what will be needed.

Access by the thrust in Global Geosciences to some of the incremental funding provided to NSF's effort in Computational Science and Engineering give assurance that this vital part of the activity will receive the attention it must have. I am aware that solar/terrestrial physics and chemistry are not included in the Global Geosciences thrust, but am also aware of the attention that NASA is according to ISTP and the close working relationship between NASA and NSF.

This brings me to my final point. Over several decades of involvement in an advisory capacity to several governmental agencies, I have come to appreciate the importance of interagency coordination and collaboration. Never have I seen better harmonization of agency activity than I discern to be the case in this instance. The report by the OSTP in the Executive Office of the President submitted to SIG (Space), "Earth Sciences Research in the Civil Space Program" is a masterpiece on the part of the executive branch of the government to begin the process of adapting the traditional agency mission orientation to the imperatives of the new *modus operandi* exemplified by the NSF effort in Global Geosciences. In addition, I have followed with keen interest and admiration the perceptive analysis of scientific strategy and implementation underway by the Earth System Sciences Committee (ESSC) of the NASA Advisory Council. The unremitting effort of ESSC to obtain agency concurrence on its recommendations has been an important contribution to effective interaction among governmental agencies. There are only minor semantic differences, but no substantive distinction, between Global Geosciences and Earth System Sciences. At this point it is appropriate to mention that the concept that "On time scales of a decade or so, the ocean, atmosphere and biosphere function as an integrated system" was at the heart of the Global Habitability initiative that NASA advanced in 1982 -- now being pursued under the rubric of Earth System Sciences. In turn, these two conceptual frameworks are quite compatible with the ICSU initiative under development, identified as an "International Geosphere-Biosphere Program: A Study of Global Change."

Thus there is a clear avenue open toward an effective international dimension to the NSF thrust in Global Geosciences.*

In conclusion, Mr. Chairman, this modest NSF effort is actually an imaginative, yet prudent, step toward fulfillment of the orignial charter of NSF. to coordinate and oversee our nation's basic research effort. I believe my long-time friend, Alan Waterman, who many years ago set the course for NSF with wisdom, imagination and circumspection, would be pleased with the thrust set before you today and the manner in which it is being advanced. I hope your committee, too, will register your pleasure by including it in your authorization.

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*Definitions (after H. Friedman) -- The Biosphere is the integrated living and life-supporting system comprising the peripheral envelope of Planet Earth together with its surrounding atmosphere so far down, and up, as any form of life exists naturally. The Geosphere is the totality of geophysical regimes comprising the lithosphere, hydrosphere, troposphere, stratosphere, mesosphere, thermosphere, exosphere, ionosphere and magnetosphere.

APPENDIX I

Global Geosciences

- Total incremental request: $18.28 M, AAEO: $16.28 M, BBS: $2 M.

- FY 1986 Base: $16.6 M, all in AAEO

- Global Tropospheric Chemistry (+$3.65M): addresses processes by which chemical substances enter the atmosphere, undergo transformations, are transported by wind systems, and are ultimately removed from the atmosphere. Significant progress has been made in instrumentation development for measuring background concentrations of chemical species to undertake study of complex interactions among chemical systems in atmosphere, oceans, land and biosphere.

- Global Ocean Climate (+$8.60M): seeks better understanding of role of oceans in climate, including general circulation and heat transfer in the oceans, seasonal and interannual variability on global scale, prediction of oceanic response and feedback to long-term changes in atmosphere. Two major projects under auspices of World Climate Research Program are "World Ocean Circulation Experiment" (WOCE) and "Interannual Variability of the Tropical Oceans and Global Atmosphere" (TOGA).

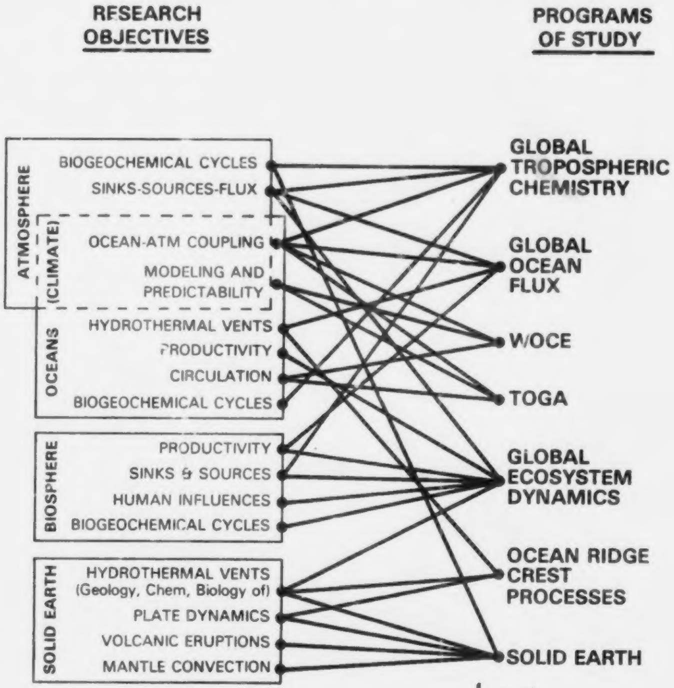
- Global Ocean Flux (+$1.37M): will identify and quantify physical, chemical, and biological processes controlling biogeochemical cycling in oceans and between atmosphere, ocean, and seafloor. Seeks to understand sources, production, and fate of biogenic materials in the sea well enough to predict their influences on perturbations significant to the global environment.

- Global Ecosystem Dynamics (+$2.00M): addresses role of terrestrial and freshwater biosphere in an integrated earth system. Focus on structure and function of tropical and high latitude ecosystems based on long term, large scale observations. Also, development and application of remotely sensed measurements to ecological problems.

- Oceanic Ridge Crest Processes (+$1.16M): examines interrelated geological, chemical and specialized biological systems at mid-ocean seafloor spreading centers, a major component of the plate tectonic system that creates and modifies earth's surface. Integrated acoustic imaging systems and ocean bottom observatories will be used.

- Solid Earth (+$1.50M): global digital seismic network will provide high-resolution imaging of earth's interior for more detailed study of patterns of convective motions now observed. Global Positioning System will be used in analyzing crustal motions; and satellite imagery coupled with ground-based studies in studying global geology.

NSF FY 1987 GLOBAL GEOSCIENCES



INTERAGENCY PARTICIPATION

	NASA	NOAA	USGS	DoD	ONR
GLOBAL TROPOSPHERIC CHEMISTRY					
GLOBAL OCEAN FLUX	X	X			
WOCE	X	X			X
TOGA	X	X			
GLOBAL ECOSYSTEM DYNAMICS					
OCEAN RIDGE CREST PROCESSES		X	X		
SOLID EARTH	X		X	X	

AAEO: 2-26-86

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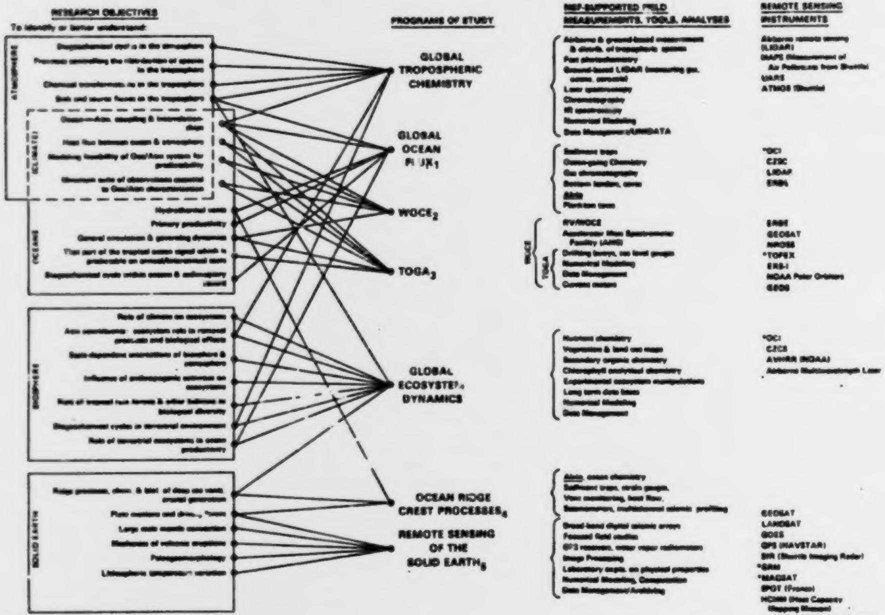
NSF FY 1987 GLOBAL GEOSCIENCES


RESEARCH OBJECTIVES
To identify or better understand:
ATMOSPHERE
Biogeochemical cycles in the atmosphere
Processes controlling the distribution of species in the troposphere
Chemical transformations in the troposphere
Sink and source fluxes in the troposphere
CLIMATE
Ocean-atmosphere coupling & teleconnections
Heat flux between ocean & atmosphere
Modeling feasibility of Ocean/Atm system for predictability
Minimum suite of observations essential to Ocean/Atm characterization
OCEANS
Hydrothermal vents
Primary productivity
General circulation & governing dynamics
That part of the tropical ocean signal which is predictable on annual/interannual scale
Biogeochemical cycle within oceans & sedimentary record
BIOSPHERE
Role of climate on ecosystems
Acid sensitivities - ecosystem role in regional precursors and biological effects
Scale-dependent interactions of biosphere & atmosphere
Influence of anthropogenic activities on ecosystems
Role of tropical rain forests & other habitats in biological diversity
Biogeochemical cycles in terrestrial environments
Role of terrestrial ecosystems in ocean productivity
SOLID EARTH
Ridge processes, distr. & hist. of deep sea vents, crustal generation
Plate motions and driving forces
Large scale mantle convection
Mechanism of volcanic eruptions
Paleogeomorphology
Lithosphere temperature variation
PROGRAMS OF STUDY
GLOBAL TROPOSPHERIC CHEMISTRY
GLOBAL OCEAN FLUX$_1$
WOCE$_2$
TOGA$_3$
GLOBAL ECOSYSTEM DYNAMICS
OCEAN RIDGE CREST PROCESSES$_4$
REMOTE SENSING OF THE SOLID EARTH$_5$
NSF-SUPPORTED FIELD MEASUREMENTS, TOOLS, ANALYSES
Airborne & ground-based measurement & chemistry of tropospheric species
Fast photochemistry
Ground-based LIDAR (measuring ga., ozone, aerosols)
Laser spectroscopy
Chromatography
IR spectroscopy
Numerical Modeling
Data Management/UNIDATA
Sediment traps
Ocean-going Chemistry
Gas chromatography
Bottom landers, cores
Alvin
Plankton tows
WOCE
TOGA
RV/WOCE
Accelerator Mass Spectrometer Facility (AMS)
Drifting buoys, sea level gauges
Numerical Modeling
Data Management
Current meters
Nutrient chemistry
Vegetation & land use maps
Secondary organic chemistry
Chlorophyll analytical chemistry
Experimental ecosystem manipulations
Long term data base
Numerical Modeling
Data Management
Alvin, ocean chemistry
Sediment traps, strain gauges
Vent monitoring, heat flow
Seismometers, multichannel seismic profiling
Broad-band digital seismic arrays
Focussed field studies
GPS receivers, water vapor radiometers
Image Processing
Laboratory expts. on physical properties
Numerical Modeling, Computation
Data Management/Archiving
REMOTE SENSING INSTRUMENTS
Airborne remote sensing (LIDAR)
MAPS (Measurement of Air Pollution from Shuttle)
UARS
ATMOS (Shuttle)
*OCI
CZCS
LIDAR
ERBA
ERBE
GEOSAT
NROSS
*TOPEX
ERS-I
NOAA Polar Orbiters
GEOS
*OCI
CZCS
AVHRR (NOAA)
Airborne Multiwavelength Laser
GEOSAT
LANDSAT
GOES
GPS (NAVSTAR)
SIR (Shuttle Imaging Radar)
*GRM
*MAGSAT
SPOT (France)
HCMM (Heat Capacity Mapping Mission)
Large Format Camera (Shuttle)

Primary Domestic Participating Agencies:

[1] NSF (lead), NASA, NOAA
[2] NSF (lead), NASA, NOAA, ONR
[3] NOAA (lead), NSF, NASA
[4] NSF (lead), USGS, NOAA
[5] NSF, NASA, DoD, USGS

*Not Yet Funded

NSF AAEO
12-16-85

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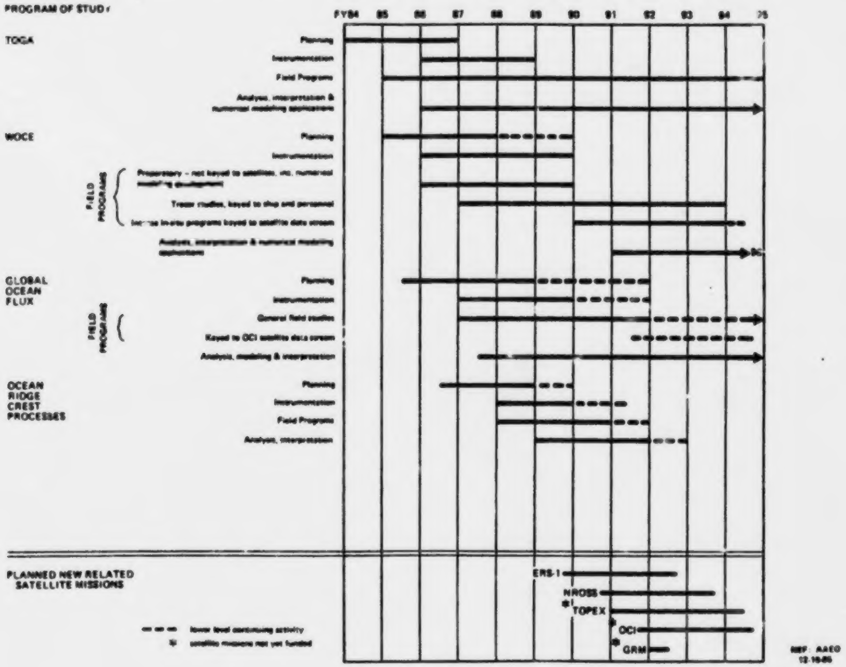
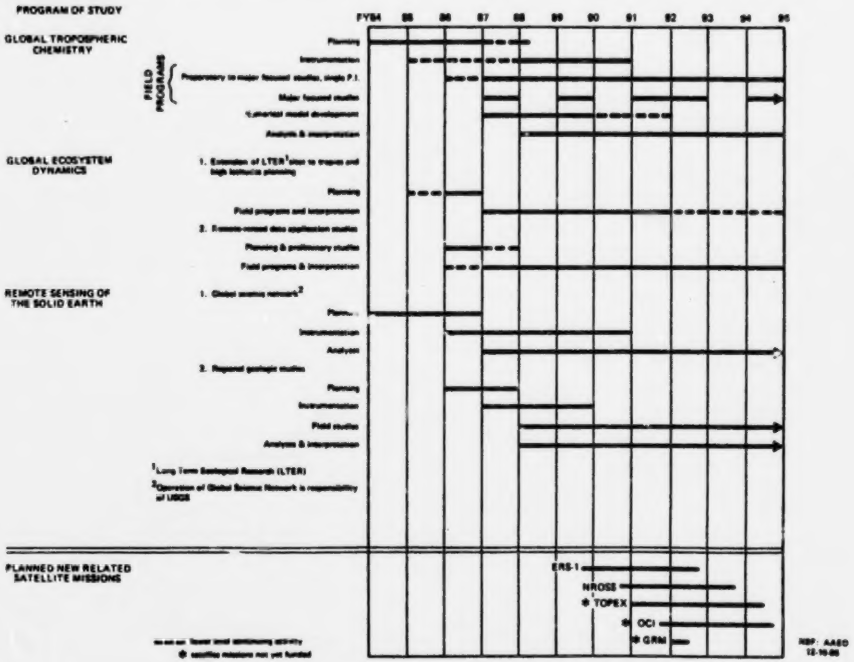
APPENDIX II (B)

GLOBAL GEOSCIENCES
MARINE COMPONENT ESTIMATED TIMELINE OF PRINCIPAL EFFORT



GLOBAL GEOSCIENCES

NON-MARINE COMPONENT ESTIMATED TIMELINE OF PRINCIPAL EFFORT



Mr. WALGREN. Thank you, Dr. Malone.

Looking at that chart, I guess I have never seen a chart that would require more coordination [laughter] than that program, and the fact that you are optimistic that it is there is good testimony, but we'll come back to that.

I understand Dr. David is with us. Let me ask him to come forward.

STATEMENT OF DR. EDWARD E. DAVID, JR., PRESIDENT, EED, INC.

Dr. DAVID. Chairman Walgren, thank you very much for the opportunity to come here today before this subcommittee to talk about fundamental mathematics or, as we called it in our report, core mathematics.

In doing that, what I would like to do is to review for you first the key findings of this ad hoc committee that I chaired on behalf of the National Research Council. That committee looked into the health of fundamental mathematics in the United States, and it found it in an unsatisfactory state, and hence the title of the report, which was "Renewing U.S. Mathematics." Then I would like to comment on what impact our findings ought to have on funding policy, particularly in this period of fiscal constraint, and then I will conclude with some suggestions for action by this subcommittee that go beyond the usual remedy of just more money.

The most significant finding, I think, of our ad hoc committee I think will not seem novel to you. It goes, however, far toward explaining how mathematics came to the state that it's in at the present time. I am referring to the widespread misunderstanding and underappreciation of the requirements that are levied on mathematics quite often. Even among sophisticated observers of science and technology, there is a tendency to believe that the necessary mathematics somehow already exists. It is there in front of you and it needs to be only applied.

That is, to put it differently, there is a rather widespread perception that new mathematics or mathematics research is discretionary, and it certainly is not. Actually the creation of new mathematics is an absolutely vital and essential part of progress in the sciences and in technology. That often escapes attention, and it is one reason why the disciplines of the applied sciences where mathematics is heavily used—and in that I might include computer science, for example—it's why those applied sciences have fared reasonably well.

The situation, however, is different in fundamental or core mathematics that were the focus of our studies in the committee. The committee, though it was looking only at fundamentals, was not indifferent to applications. Far from it. Mathematics is what the chairman of the House Science and Technology Committee, Don Fuqua, has called a foundation discipline, and it has been a foundation discipline since the scientific revolution was set off by the likes of Newton and Galileo.

The National Research Council sought to reflect that fact by putting on our committee several people that were not mathematicians but were part of the user community, the people who really draw heavily on mathematics. One of these people was Gerard Debreu, the professor from Stanford University. During the period that we were meeting, he was awarded the Nobel Prize in economics for work that exploited new mathematics.

I would like to put a personal note in here. I am not a mathematician myself either—I am an engineer—but I have seen the importance of new mathematics firsthand in my career at Bell Laboratories, at Exxon, and of course in the Federal Government.

At Bell Laboratories I was witness to the blossoming of technologies, including information technologies and computing, that would have been impossible without a mathematical basis or a mathematical framework from which to work. Out of that, because of that experience, I am not surprised that new mathematics is central to the design of high-density integrated circuits, for example; the design of information networks; and even the design of solution procedures, that is, algorithms, without which even our fastest computers would be quite ineffective.

In my most recent incarnation, which was with Exxon, I found that mathematics is used in advanced technologies for finding oil, for improving the yields from existing fields, and for creating new chemical and oil refining processes. It is vital to the defense effort, as you well know, and it will become more so, particularly when such ambitious undertakings as the SDI are in front of us.

The point is that mathematics is absolutely central to the progress of most scientific and engineering disciplines, and the outlook is for it to become central to progress in more and more fields, particularly the life sciences and the social sciences. The trend has, of course, been accelerated by parallel advances in instrumentation and computing. Again, mathematics is a foundation discipline in that.

That fact should have profound implications for the Nation's effort to maintain our science and engineering base. A strong mathematics research enterprise is vital to this Nation's efforts to bolster our international competitiveness, our economic growth, and to create jobs based on advanced technology or even on existing technology, and to ensure a strong defense.

This matter is not as widely known as it should be, and you might very well ask, "Why is that so?" I think it is primarily because mathematics is at least one step removed from the immediate and the obvious, and that one step removal obscures its central role from those who only observe the scene.

Now what did our committee find about the state of mathematics in this country? What did we recommend, and what has happened since the report was issued about 18 months ago? I can boil down what we found about the state of mathematics to just a pair of statements: First, because of declines in research funding Ph.D. production in mathematics has slowed to the point that the mathematics community is not replacing itself. Second. Federal support for fundamental mathematics is badly out of balance for Federal support for the scientific and engineering disciplines that mathematics supports.

Let me explain these statements in a little more detail. We found that from the late 1960's to the early 1980's, Federal support for mathematics shrank by more than a third in real dollars, while

Federal support for other scientific disciplines was growing. This was documented in data that was collected for the first time under the aegis of our committee.

I would like to show you a summary table. I hope you can read it; maybe not, though. Can you focus it a little bit, or maybe it's just my eyes. You can see from that chart the kinds of imbalances that have developed between mathematics and other fields of research. The top line shows, for example, that there are just as many mathematicians in U.S. colleges and universities as there as physicists or chemists, yet the mathematics faculty received only about two-thirds of the Federal research support in that year. Only a small percentage of the graduate research assistants are supported, as is shown there, and look at the postdoctoral level—50 in mathematics, compared to 1,200 in physics and 2,500 in chemistry.

Now, briefly, these imbalances developed because of the underappreciation that I mentioned before, and because mathematics and computer science were being lumped together in the data that was collected and published by the NSF and other Federal agencies. That lumping together, that aggregate figure, obscured that the growth was all in the applied fields of computer science, and it masked the decline in core mathematics support.

Another key reason is that mathematics research support has been heavily concentrated in just two agencies, NSF and DOD. When the Mansfield Amendment and its aftereffects caused DOD to drop nearly all of its support for core mathematics in the late 1960's and early 1970's, the NSF simply could not take up the slack.

To begin correcting this situation, our report makes some conservative recommendations—and I say "conservative" in spite of the fact that the recommendation calls for more than a doubling of support over the next 5 years. The increases would come, however, from a very low base, from about $80 million per year in 1984—these are in 1984 dollars—to $180 million per year, also in 1984 dollars. In other words, this graph is shown in constant dollars.

In the last 2 or 3 years, and particularly in the last 18 months, there has been important but still insufficient progress toward meeting the funding goals that we laid out. The most important source of the upturn by far has been the National Science Foundation, under the rather determined and devoted leadership of Erich Bloch. The NSF is now supporting some 675 graduate students and some 220 postdoctorals in mathematics.

The most significant future gain should—and I underline "should"—come from the DOD. Unfortunately, the Gramm-Rudman Act will have the effect of sharply reducing DOD's contract research, but the DOD university research initiative may offset part of this. Now the largest gain at DOD is likely to be in ARPA or DARPA, which started a $1 million mathematics program last year and increased it to $5 million in 1986.

Mr. Chairman, before we take that Vu-Graph off, the thing that startles me about it are the small numbers on the left-hand part of the curve. The idea that the entire Federal Government supports at the present time only about 100 million dollars' worth of core mathematics in this country was really quite startling to me, and I might say from my own knowledge that industry supports really rather little research in core mathematics, so if you added all of the money that goes into fundamental mathematics research in this country, it would not be much larger than what you see right here.

Mr. **Walgren**. Let me ask you, you mentioned you expect or would anticipate the greatest increase to come from DOD. Why is that? It would seem that their line has been, ratewise, keeping up with NSF's change in rate of funding.

Dr. **David**. Well, this report and indeed our view of the importance of mathematics for DOD has been rather widely registered, both in the Office of the Secretary of Defense and in the services. We see some movement there toward going back to supporting core mathematics research, rather than research which only has a clear relevance to the mission of the DOD.

Mr. **Walgren**. And how did that come about? The Mansfield amendment, is that what you mentioned?

Dr. **David**. That is basically a paraphrase of the Mansfield amendment wording, yes.

Mr. **Walgren**. And do graphs show them getting out of mathematical support?

Dr. **David**. Yes, they do.

Mr. **Walgren**. Previous to 1982, I gather.

Dr. **David**. Yes. That was in the late sixties and the early seventies, mostly the early seventies, when that happened.

Mr. **Walgren**. OK. Thank you. Please continue.

Dr. **David**. Well, I was going to review those numbers but I think they are quite clear. The appropriations in fiscal 1986 were about $105 million before Gramm-Rudman, so I think you should read this curve as about $100 million in 1986. In other words, the support has been growing but only at about half the rate that we recommended in the report, and so I don't think that the increases—though they have been well-meaning and indeed appreciated—have not yet improved the situation to the point where the mathematics community has begun to be able to renew itself.

The supply of trained academic mathematicians is actually worse than it was 2 or 3 years ago. Ph.D. production in that period has dropped from about 800 to 750, and there is an annual shortfall of about 150 Ph.D.'s available to fill full-time faculty positions at the 4-year institutions. As existing faculty age—and they are aging pretty fast—their retirement rates are accelerating, so we expect to see this situation not improve very much, and this doesn't take account of the demand for Ph.D. mathematicians in industry, which is also increasing substantially. There are also rather strong indications that the generation of new mathematical ideas has been slowing down, even while the new applications which demand advances in core mathematics have been accelerating.

Now the mathematics community hasn't been oblivious to all this, and they have moved to try to correct the situations as best they can. They are making their case known and they are doing it forcefully, as you may see more fully in my written testimony.

Let me just conclude here by urging the committee to support and augment the increases in mathematics funding being undertaken by the NSF. Further, let me remind you again that, as Don Fuqua has said, mathematics is a foundation discipline. What that means is that mathematics should be central to all deliberations about science policy, when setting priorities and when authorizing funds.

This is not the situation today because mathematics does not require nearly the funding level of experimental fields, because there is little equipment involved, though there is getting to be more. There is a tendency to forget mathematics. To help correct that tendency, I would urge that the Committee on Science and Technology engage in a careful dialogue with representatives of the mathematics community, and perhaps even hold hearings on the subject.

The goal should be to bring the discipline more to the forefront of the committee's thinking, and to put you in a position to ask insightful questions about this campaign to renew U.S. mathematics. Your support I think is essential if we are going to restore this critically important field to health during the next decade.

Thank you very much, Mr. Chairman.

[The prepared statement of Dr. David follows:]

STATEMENT OF

DR. EDWARD E. DAVID, JR.

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

U. S. HOUSE OF REPRESENTATIVES

FEBRUARY 26, 1986

Mr. Chairman and Members. Thank you for the opportunity to appear before this subcommittee to discuss the support of research in mathematics. I have been invited to address the findings of the Ad Hoc Committee on Resources for the Mathematical Sciences, which I chaired.

The Committee was organized in 1981 under the authority of the National Research Council, the principal operating agency of the National Academy of Sciences and the National Academy of Engineering. The Committee looked into the health of fundamental mathematics research in the United States. We found it in an alarming state -- hence, the title of our report, Renewing U.S. Mathematics: Critical Resource for the Future, which was released in June, 1984.

I will summarize and update the key findings of the ad hoc committee, and comment on what impact our findings should have on funding policy, particularly in this period of fiscal constraint. I will conclude with some suggestions for action by this subcommittee that go beyond the universal remedy of "more money."

Preliminary Matters: Definition of "Mathematical Sciences"

Our charge was to assess the health of fundamental mathematical research. The term "mathematical sciences" is now commonly used for "mathematics" in a broad sense. The ad hoc committee followed that convention. We need a clear understanding of what is and what is not included under the umbrella of "mathematical sciences."

Three major divisions make up "mathematical sciences" -- pure or core mathematics, applied mathematics and statistics. Within each of these divisions exist numerous sub-fields, too extensive to list today. The discipline is concerned with the creation of new mathematical and statistical concepts and methods that push forward frontiers, not only in mathematics, but in all fields of science and technology.

Not included is computer science. While computer science makes pervasive use of mathematics, it has been recognized for more than a decade as a separate discipline.

Also not included are the myriad applications of known mathematical methods to other scientific and technological fields.

While more a question of scope than definition, it is worth noting that the ad hoc committee did not review the state of mathematics education. While the full spectrum of mathematics education -- from kindergarten through university -- is of vital importance to the nation, it was not within our charge.

Key Finding: Mathematics as a Foundation Discipline

The most significant finding of our committee will not seem novel. But it goes far toward explaining how mathematics funding came to its present state. I am referring to the widespread misunderstanding and under-appreciation of the role of mathematics in our scientific and technological society, today.

Even among sophisticated observers of science and technology, there is a tendency to believe that the necessary mathematics already exists and needs only to be applied. That the creation of new mathematics is an absolutely vital and essential part of scientific and technological progress often escapes attention.

That is why the disciplines of applied science, which heavily use mathematics -- including parts of computer science -- have fared reasonably well both in advancement and funding support. The situation is different in fundamental or core mathematical science, which was the focus of our committee's study.

Not that our committee was indifferent to the issue of applications. Far from it. Mathematics is what Chairman Don Fuqua has called a "foundation discipline," and it has been since the scientific revolution fostered by such giants of the past as Galileo and Newton.

The National Research Council sought to reflect that fact by including several people on our committee who were not mathematicians, but who were from the "customer community" for mathematics. Such people included Gerard Debreu, who was awarded the Nobel Prize in Economics for work that exploited new mathematics.

I am not a mathematician either. But I have seen the importance of new mathematics firsthand during my career at Bell Laboratories, Exxon, and in the Federal Government. At Bell Labs, I was witness to the blossoming of modern communications and computing, developments that would have been impossible without new mathematics.

New mathematics is central to the design of high density integrated circuits, the design of information networks, and the design of solution procedures without which even our fastest computers would be ineffective.

It is used in advanced technologies for finding oil, for enhancing production from existing fields, and for creating new chemical and oil refining processes. It is vital to the defense effort, and it will become more so, particularly in such ambitious undertakings as the Strategic Defense Initiative.

The point is that mathematics is absolutely central to progress in many scientific and engineering disciplines. And the outlook is for it to be so for more and more fields, a trend being accelerated by parallel advances in instrumentation and computing.

I commend to your attention the lead editorial in last months' American Scientist, in which Lewis M. Branscomb of I.B.M. points to a new unity in science and to the central role of "the emerging new mathematics" in that unified sense.

Again, mathematics is a foundation discipline. That fact should have profound implications for the nation's effort to maintain our science and engineering base and to sustain efforts to bolster the competitiveness of our industry, to promote economic growth and jobs based on advanced technology, and to assure a strong defense.

Specific Findings of Ad Hoc Committee

What did our committee find about the state of mathematics? What did it recommend? What has happened since our report was issued eighteen months ago?

The specific findings of the ad hoc committee can be summarized in two statements:

- Because of declines in research funding, Ph.D. production has slowed to the point that the mathematics community has not been replacing itself.

- Federal support for fundamental mathematics is badly out of balance with the support of the scientific and engineering disciplines that mathematics serves.

Let me explain these statements in more detail. Over the decade 1973-1983 the production of U.S. citizen Ph.D.'s in the mathematical sciences was cut in half. I will say more about manpower later.

As for the imbalance I mentioned, the ad hoc committee found that from the late 1960's to the early 1980's, federal support for mathematics shrank by more than a third in real dollars, while at the same time federal support for other scientific disciplines had grown. This was documented in data that was collected for the first time under the aegis of the ad hoc committee.

Comparison By Field of PhD Support

The chart in Appendix I provides a comparison of federal support in institutions of higher education for three fields of science in 1980. The numbers document the dramatic effects on mathematics of this decline in overall federal support.

These 1980 figures make manifestly clear the kinds of imbalances that have developed between mathematics and other fields of research. There are just as many mathematicians in colleges and universities in the United States as physicists or chemists.

Yet only about two-thirds as many mathematics faculty received federal research support. Only a small percentage of the graduate research assistants are supported. And look at the postdocs--50 in mathematics, compared to 1,200 in physics and 2,500 in chemistry!

These imbalances developed because of the indifference I mentioned before and because mathematics and computer science have been lumped together in the data of the National Science Foundation and other Federal agencies. In the aggregate figures, the growth of computer science masked the declines in core mathematics support.

Another key reason is that mathematics research support has been heavily concentrated in just two federal agencies -- DOD and NSF. When the Mansfield Amendment and its after-effects caused DOD to drop nearly all its support for core mathematics research in the early 1970's, the NSF simply did not take up the slack.

Ad Hoc Committee Recommendations

To begin correcting this situation, Renewing U.S. Mathematics: Critical Resource for the Future makes some conservative recommendations -- even though it does call for more than a doubling of support over the next five years. The increases would come from a low base -- from $80 million per year in 1984 (in 1984 dollars) to $180 million per year (in 1984 dollars) at the close of five years.

Progress in Recent Years

In the last two or three years, and particularly the last 18 months, there has been important, but still insufficient progress toward meeting these funding goals.

The most important source of the upturn by far has been the NSF, under the determined leadership of Erich Bloch. The NSF is now supporting over 600 graduate students and 200 postdocs in mathematics.

At DOD, Gramm-Rudman-Hollings will have the effect of reducing contract research sharply, but DOD's University Research Initiative may offset part of this. The largest gain at DOD is likely to be at DARPA, which started a $1 million mathematics program last year and increased it to $5 million in FY 1986.

Federal Support: Shortfall in Present Levels

The chart in Appendix II shows the total federal support for mathematical research at $93 million in FY 1985, the last year for which there are firm numbers. FY 1986 appropriations totalled $105 million before any impact from Gramm-Rudman-Hollings was felt. Therefore, total support is about $100 million.

Allowing for inflation, federal support for mathematics is still $100 million short of the support levels recommended by our committee. In other words, support has been growing, but at only about half the rate necessary.

Unfortunately, these increases have not yet improved the situation to the point where the mathematics community has begun to renew itself. The supply of trained mathematicians is inadequate. The manpower situation is actually worse than it was two or three years ago.

Ph.D. production has dropped again, from about 800 per year to about 750 per year. There is an annual shortfall of about 150

Ph.D.'s available to fill full-time faculty positions at the four-year institutions. As existing faculty age, retirement rates are accelerating. Demands for sophisticated computational applied mathematicians are rising sharply. And there are strong indications that the generation of new mathematical ideas has been slowing, even while new applications for these ideas are accelerating.

Response of the Mathematics Community

The report talked not only about funding recommendations to the Congress and the Executive Branch. The committee called on the mathematics community to:

- o Develop mechanisms for setting priorities and making their needs known;
- o Exercise strong leadership in pre-college education; and
- o Study in-depth the problems of collegiate-level mathematics.

I have been impressed by the rapidity and strength with which the mathematics community has responded to the challenge.

Three examples are worthy of notice:

1. Creation of Board on Mathematical Sciences

Within the past two years a new Board on Mathematical Sciences (BMS) has been established at the National Research Council. The Board is charged with maintaining an accurate profile on the health of the nation's mathematical research. In a sense, the Board picks up where the ad hoc committee left off.

The Board on Mathematical Sciences will issue this spring two substantial reports:

- o A review of the state of mathematics internationally; and
- o A survey of U.S. Mathematics, which looks at the intellectual state of the field in far greater detail than the ad hoc committee could have done.

Through the Board's leadership, the mathematical sciences research community will maintain an up-to-date picture of needs of mathematics research.

2. Establishment of Mathematical Sciences Education Board

In an unprecedented display of national leadership, the mathematical research and teaching communities united in a recommendation that the National Research Council establish a Mathematical Sciences Education Board (MSEB).

This new board was launched last fall. The primary purpose of the Board is to provide a continuing national overview and assessment capability for mathematics education from pre-kindergarten through the undergraduate level of education.

As one of its foci, the Board is working to develop model standards and curriculum for mathematics education. Other areas of review include: testing, impact of technology on mathematics education, teacher education, information collection and dissemination, and international comparisons of mathematics instruction.

Close working relationships with grass-roots entities -- school boards, chief state school officers, state legislatures, parents and others -- will strengthen the dissemination and eventual usefulness of work products coming from the Board.

3. Development of Undergraduate Study

A final example of leadership within the mathematics research community has been planning over the past two years for a study of the collegiate mathematics enterprise. A proposal entitled "College Mathematics and the Year 2000" was recently submitted for review to the National Research Council.

The 30,000 collegiate mathematics teachers instruct for a wide spectrum of need:

- Students in academic areas that use mathematics;
- Mathematics majors;
- Pre-college teachers; and
- Quantitative literacy of the general population.

Because of the profound effects and enormous potential of this educational mission, improved quality in all these areas must become a national goal supported by a firm federal commitment. A form of working partnership between universities and government appropriate to the fiscal era we are working in will be called for.

Specific Recommendations for Congress

Let me conclude by urging the committee to support and augment the increases in mathematics funding being undertaken by the NSF. Further, let me remind you again that, as Chairman Don Fuqua said, mathematics is a foundation discipline. What that means is that mathematics should be central to all deliberations about science policy, and when setting priorities and authorizing funds.

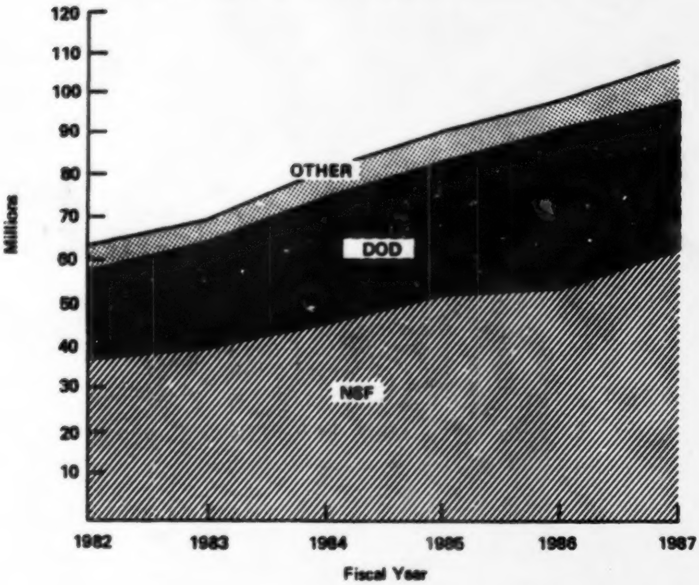
Unfortunately, this is not the situation today. Because mathematics does not require nearly the funding levels of experimental fields, there is a tendency to forget it. To help correct that tendency I would recommend that the Committee on Science and Technology engage in a careful dialogue with representatives of the mathematics community. The goal should be to bring the discipline more to the forefront of the committee's thinking and put you in a position to ask insightful questions about the campaign to renew U.S. mathematics. Your support is essential if we are to restore this vital field to health in the next decade.

Comparisons of Federal Support in Institutions of Higher Education for Three Fields of Science, 1980

	Chemistry	Physics	Mathematical Sciences
Doctoral scientists in R&D	9,800	9,200	9,100
Faculty with primary or secondary activity in R&D	7,600	6,000	8,400
Faculty in R&D federally-supported	3,300	3,300	2,300
Approximate annual Ph.D. production	1,500	800	800
Graduate research assistants federally-supported	3,700	2,900	200
Postdoctorals federally-supported	2,500	1,200	50

Sources: NRC Survey of Doctoral Recipients,
National Science Board--Status of Science Review

APPENDIX II



Federal Support of Basic Academic Research in Mathematical Sciences

Federal Support of Basic Academic Research in Mathematical Sciences (FY)

	82	83	84	85	86 3)	87 4)
NSF 1)	34.2	37.1	45.6	52.7	57.2	65.5
DOD 2) (AFOSR, ARO, ONR, DARPA)	23.3	26.5	29.9	32.3	42.4	39.1
Other 2) (DOE, NASA, NIH)	4.3	4.8	4.9	5.5	5.9	4.8
Total	61.8	68.4	80.4	90.5	104.5	109.4

1) DMS represents about 90%.

2) This is based on estimates of the mathematics extramural component of some programs.

3) These are pre Gramm-Rudman, SDI and University Research Initiative figures. Their eventual effects may cancel each other.

4) The President's budget. Estimates of ultimate program emphasis (see 2) and future effects of URI and SDI make these tentative, especially outside NSF.

Mr. **Walgren**. Thank you, Dr. David. We appreciate that survey, and it has been a fascinating series of presentations, chemistry being the only one of great satisfaction, at least in terms of the adequacy of response. I suppose we ought to give Dr. Gray a chance to pitch in here now, after having expressed support for the NSF's response, and the other subjects being a little bit on the shorter side of things, I'm sure, but maybe you would like to add something.

Dr. **Gray**. It is in my prepared testimony that, like everyone else, we call for more in terms of getting us where we felt we should be. In fact, our report calls for a 25-percent increase in the NSF budget for chemistry, and my remarks are made in the context of the present situation, where we realize that the deficits are very high and we are trying to act as responsibly as possible.

Mr. **Walgren**. Well, I think that is really——

Dr. **Gray**. We could always call for more, but we think Mr. Bloch, with the problems he is facing, has made up an excellent budget that takes into account the excitement that is in various areas, and has called out chemistry as a high priority area within the NSF budget. We agree with that. Obviously we ask for more in terms of what we really need to do the job, in terms of instrumentation and all of the other areas in question, so I'm just talking about relative satisfaction.

Mr. **Walgren**. I understand. No, I don't mean to indicate that——

Dr. **Gray**. I probably wouldn't be able to get out of this room, my chemistry friends, if they thought I had actually testified that we were really satisfied.

Mr. **Walgren**. OK. We'll put you down as very unsatisfied and yet very appreciative of the NSF's response to the Pimentel report.

Dr. **Gray**. No, I want to commend Mr. Bloch. I think Mr. Bloch has done an outstanding job, and that's really what I wanted to say.

Mr. **Walgren**. Yes. Well, I think that there really is a lot of appreciation of the development of these budgets under Mr. Bloch's administration at NSF.

Dr. **Gray**. I think he has very carefully looked at our report. I think he has looked into it. He has looked into what is real and what is hyperbole. He has looked at where there are real opportunities and has called out priorities that are quite appropriate, and for that I commend him.

Mr. **Walgren**. Yes. Let me ask a general question, of whether or not you are optimistic about the prospects of your scientific disciplines over the next 10 years. If you could guess where you would be in 1995, what are your instincts about what lies ahead. I know it's full of promise, but the question is whether you think this Government as you see us is up to providing the resources to enable those promises to become real. Would anybody like to address the general question of optimism? The American public is very optimistic, as you know. That seems to be part of our nature.

Dr. **Gray**. Yes. Well, let me say something first. I do believe that chemistry is in its golden age right at the present time. People in quantum mechanics, in particular Professor Durak in the late twenties, said that chemistry was now solved. We have been wrestling with that proposition for about 60 years.

But it is now true that theoretical chemists, using high-speed computers, using mathematics, using everything at their disposal, now are able for the first time to really calculate complex molecular systems with some degree of reliability. It is also true that the synthetic revolution has occurred; it is true that the laser revolution has occurred.

All of these things have come together and put chemistry right now in its very most exciting period, and this will continue. The benefits will come between now and the end of this century. I am absolutely convinced, just as physics was undergoing a revolution in the twenties, chemistry is undergoing its revolution in the eighties and in the nineties.

I don't know whether we have enough support, and I am very, very concerned about comments that were made earlier in this testimony, in this hearing, about education underlying the whole system. I am very, very concerned about those points and the fact that if you go below doctoral education, you get into undergraduate education, and below that into secondary education. These are real problems. The chemists of this country are not arguing their case against other cases as being irrelevant.

These are very, very real issues for this country which we have to address. I believe that with the limited resources of the National Science Foundation, one has to concentrate and focus on things that can be done and the huge problems of the country in education have got to be tackled, where I don't know. I am very frustrated. I'm sure you are, too, Mr. Chairman.

Mr. **Walgren**. Yes; we are.

Dr. **Gray**. We are very, very frustrated about this point. It's a real problem. Nothing that has been said today, that I have heard, I disagree with in terms of the urgency of the issues.

Mr. **Walgren**. Yes. You know, it is very frustrating, and so important, too. With trying to be sure not to trample on minority views at this point, or views of the minority, in this whole area I certainly feel—I don't know whether this is the place to say this kind of stuff—that first as citizens we have to solve these underlying problems of imbalance in these Federal budgets, or else nothing can prosper.

I am personally very struck these days by sort of graphing out in my own mind the sort of great increases in commitment to interest payments that are programmed into the system at this point, and, therefore, will automatically become imbedded costs in all future budgets and, therefore, occupy the field, in many ways, of available effort. When you look at the scale of that versus the scale of what we are dealing with here, it just is stunning.

Dr. **Gray**. It is stunning.

Mr. **Walgren**. We are, in 1986, we are paying between $80 and $100 billion more in interest costs than we did in 1980, so the increase in the tax dollars going to interest costs over these 5 years has been something in the range of $80 to $100 billion. Now if we walk down that slope at the same rate we walked up it—and that is what Gramm-Rudman would anticipate, that we were 5 years getting into this and now we're going to set ourselves a glidepath down to zero, which we'll be 5 years getting out of it—and if you look at the interest costs necessary to carry the debt underneath that whole bell curve, in 1992 we will be looking back at literally, in each budget year from 1992 on, double the $80 to $100 billion in imbedded interest costs.

So in 1992 we will have embedded in increased interest costs in every future budget, something in the range of $169 billion—and that's the low estimate—in increased interest costs over and above what the state of affairs would have been had we taken a different course in 1980. The reference, the starting reference point is that the Federal Budget was $27 billion out of balance in 1979 and went to $212 billion out of balance within 3 years, so there was this real explosion in the size of the debt that was added each year.

Well, my point is simply this: We look at these numbers in the National Science Foundation of a total of $1 billion. We could multiply that literally by 160 to 200 times by 1992, if we had just access to the money that will have to be wasted on interest at that point, and wasted if you define waste as a tax dollar committed for no constructive result during that year. It will just be a dollar taken from the taxpayer and transferred to somebody else for no real product at that point.

And so to see that much waste being built into the system and crying out for—you know, wouldn't it be nice to double the National Science Foundation's budget? It would only take $1 billion, and we have put $80 billion of lead weight around our feet simply on interest costs since 1980, and before we are done it will be $160 billion around our feet in terms of weight.

So I just say that to try to underscore the dimensions of these things. It is so hard from a public standpoint to measure comparable sizes of programs. We are all for a certain purpose and we applaud a program in that area, but the real question is how you measure the size of that program against the size of other kinds of commitments. That's where the public has a great deal of difficulty keeping up with the Government budgets.

I hope fundamentally as scientists that you will—and the reason I say this is, I like to encourage everybody to do their part in trying to play whatever citizen role can be constructive on that level, in hopes that we will preserve some resources and some of the social effort that we have to give to each other, in order to strengthen these areas.

Well, I don't mean to say that, except it's on my mind. Let me think of a couple of things that I wanted to—oh, other comments on the optimism question? Yes, Dr. Malone?

Dr. MALONE. Thank you, Mr. Chairman. I have to leave in a few moments to talk to my several hundred science teachers and aspiring scientific literary citizens in Connecticut, but let me say two things.

One is that I am fundamentally optimistic, and, I think, that the driving force is going to be the competitive pressures from Japan, Western Europe, the Soviet Union, and even the United Kingdom; which has its own set of problems, though. I think that it is generally recognized that science and technology are the underpinning of maintaining competitive strength, and I think that will emerge even if it means—spare the words—revenue enhancement.

Second, since I do have to leave, Mr. Chairman, and you mentioned the complexity of the undertaking to which I refer—and, by the way, I too am quite satisfied with Mr. Bloch's decision—I did have in my testimony a comment on the sort of landmark report by OSTP on how this would be managed, and there is emerging a study of the Earth Systems Sciences Committee of NASA which is remarkable in that all the recommendations have received agency concurrence before they are issued.

I know that Jerry Niesner used to say that he presided over a mild form of anarchy, in looking at the scientific establishment in Washington. I think that is to be preferred to the hierarchal structure that I have observed in the Soviet Union, for example, but I do think that bringing that mild scientific anarchy into order has been met with these two reports, and I commend them to your attention.

Mr. WALGREN. Is there a lead agency concept here? Is there one central administrator of the whole——

Dr. MALONE. The oversight is going to be within OSTP itself, with the scientific oversight provided by the National Research Council, according to the recommendations in the OSTP report, and it is a shared responsibility of NASA, NOAA, NSF, USGS, DOD, ONR.

Mr. WALGREN. Yes, but there is not a single administrator at that point, is there?

Dr. MALONE. Not at this point, no, and that's the problem that OSTP has been wrestling with. After watching turf battles in Washington for the last quarter century, I think they are within reach of a sensible solution, so I want to reassure you that it's not as chaotic as this chart might lead you to believe.

Mr. WALGREN. Yes. What's the key to that? What enables that to happen? We have no direct experience with it but we have been working with the nutrition monitoring area, which has a similar graph, and yet there has been no progress in that at all and terrible turf disputes, and people engage in endless meetings out of which they just go right back and continue whatever it is they wanted to do before they came to the meeting. Is there anything that distinguishes this area from that and helps it to function better?

Dr. MALONE. I have pondered that same question, and all I can come up with is that the merit of the program and the excitement of participating is a powerful ameliorating effect on this natural inclination to grab.

Mr. WALGREN. And it is pure science, too. Part of the problem with the other is that there is a political——

Dr. MALONE. Oh, yes. Yes.

Mr. WALGREN [continuing]. And lots of real interest involved, and this is really quite pure science.

Dr. MALONE. Yes, but would you excuse me, Mr. Chairman.

Mr. WALGREN. Yes, and I apologize for having kept you. I realize you do have a plane. I'm sure you will make it, and we do appreciate your having come.

Dr. MALONE. If you have any questions, I would be glad to answer them in writing, sir. Thank you.

Mr. WALGREN. Thank you very much.

Let me see if there is anything else compelling at this point. I wanted to ask you, Dr. Compton, whether you would be willing to stay at 15 centers. Where is this line? I guess NSF wants to have 25 engineering centers, and they presently have how many? Fifteen by the end of 1987, with a goal of 25? Where is the cutoff point for, as you say, staying with what you've got and making those work, as opposed to increasing the numbers?

Dr. COMPTON. I think there are really only two criteria that one should apply to that, and those criteria do not exist as absolutes before the fact. It seems to me first you have to ask the question: Are there viable university programs that would qualify for this type of funding? I suspect there are many more than 25 that will qualify and could qualify for that. The evidence I think is that a very large number of good proposals have already been submitted in the last two rounds, so there is nothing magical about the 25. In fact, there have been some suggestions that it should go to 100 or more. The issue, it seems to me, comes down to quality and the funding level, and ensuring that they are funded at a level on which they are viable. So the number should not increase at the expense of viability of the individual.

Mr. WALGREN. We really don't have concrete, measurable ways of looking at these centers as yet. They are too new. Is that fair to say?

Dr. COMPTON. They are too new, that is correct. On the other hand, there is experience with program funding in a variety of agencies in the country. I think one can be very optimistic that these will be successful. The unique thing here is the involvement of the industrial sector in them, and with the start and the efforts that have been made by the Foundation in ensuring that this involvement is viable and appropriate, I think one can foresee a high probability of success.

Mr. WALGREN. Dr. Smelser, you may not have been here when Mr. Bloch testified, the Director of the Foundation, but he indicated that they were at least accounting for some of the computational support that the social sciences are interested in, in a separate budget. I may be in over my head here, but——

Dr. SMELSER. Perhaps I am, too.

Mr. WALGREN. I guess what I am asking——

Dr. SMELSER. I did not read his testimony but I am aware that he spoke.

Mr. WALGREN [continuing]. Is, that would be helpful, would it not, so that those amounts are not set off against whatever the year-to-year effort in social sciences might be.

Dr. SMELSER. Of course, and one would just simply--I believe I will have to simply say that one would have to do some proper research to see exactly what the spillover of those computational facilities are with respect to computational needs in survey analysis and other lines of social science research. I cannot give you a one way or the other response to that assertion. I'm sorry.

Mr. WALGREN. I have always had the sneaking feeling that when they put social and behavioral together, that somehow there might be an ability to direct all the money toward whatever it was they wanted, and in these instances perhaps more behavioral than social. How do the pure social sciences fare when you are in one line item along with behavioral, which I gather can cover a very wide range of other disciplines?

Dr. **Smelser**. The actual breakdown of granting programs in the National Science Foundation is, I guess, the product of some historical accidents. Behavioral sciences are with neural, and within that we have a discipline which we primarily regard as social science, namely anthropology, and then over on the social and economic sciences we discover the disciplines we normally associate with that—that is to say, sociology, political science, economics—on that side.

A lot of discussion among us and, I am sure, among people in the National Science Foundation is what would be the optimum structure for that giving. At the present time, and I now speak only for myself, I believe that certain subjects like social psychology tend to fall through the cracks because they don't fit precisely in either, given that division.

I also believe that, given the fact that the programs with a considerable number of exceptions are disciplinary in character, this may build in—just as academic departments in universities build in some kind of encrustation—the fact that so much of the funding is along disciplinary lines may, given the kind of interdisciplinary ferment that I and others have tried to convey to you in different ways this time and last, may—I believe that sensitivity to those new developments has to be always kept in the forefront because it is very likely that disciplinary panels will not appreciate the kind of excitement that is going on.

Mr. **Walgren**. I see.

Dr. **Smelser**. I should also say that if you try to get a committee such as mine to come up with a consistent distinction between behavioral and social science, you will find that you will have to increase our budget so that we can have increased numbers of meetings to try to sort that out. Many of us believe that the distinction is a historical one without proper analytic basis, and I am among those.

Mr. **Walgren**. Yes; you have a report coming, don't you, in the social and the behavioral sciences?

Dr. **Smelser**. Yes; it's in the drafting stages. We think we are going to make the deadline. It is due to be reviewed in July.

Mr. **Walgren**. I see.

Well, is there anything anyone else would like to add? Dr. Compton?

Dr. **Compton**. Could I just add one thing? There was some discussion earlier about the need for facilities and the large amounts of moneys needed. I would just encourage you to avail yourself of the recent meeting that was held at the Academy by the Government/Industry/University Roundtable on university facilities, to discuss that very topic and to look at a variety of other options, perhaps, for seeing if there could be other sources of funds brought to bear. I'm sure the director of the roundtable, Dr. Dale Corson, would be pleased to supply you with information concerning that meeting.

Mr. **Walgren**. That's a good footnote.

Dr. David.

Dr. **David**. Mr. Chairman, in terms of your question about what will happen over the next 5 years, and whether we are optimistic or pessimistic, let me take an obverse view or a reverse viewpoint.

I am not as optimistic, perhaps, as other people are about the next 5 years. There is no doubt in my mind that science will progress and technology will, too. The question is, will it progress at a rate which is satisfactory to do the things the Nation wants to see done, and I have some worry about this.

As was said earlier today here, science and technology, too, progress because of individuals. Of course, individuals need help, both in terms of funds and sometimes in terms of guidance, but fundamentally progress is a matter of individual inspiration, and sometimes perspiration, as Edison once said.

My feeling is that if you look at the outline of Federal funding and, to some degree, industry funding in the years ahead, as we project it, it is dominated by large projects. In terms of the Federal Government, you see the SDI, of course, and the heavy emphasis on what has been called the fifth generation computer project of the Department of Defense, the superconducting supercollider, the Space Station, and similar large initiatives.

In an era in which we have the Gramm-Rudman bill and the effort to get ourselves back into a reasonable fiscal condition—which I certainly agree with, and I agree with your comments about that—small science and particularly mathematics could be squeezed very considerably, because the programs that will be protected are the ones that are visible and large and have political appeal, if you will pardon the expression.

I am quite concerned that the efficiency of the process of producing science and technology will suffer substantially. There will still be good science and technology produced, but it will be done at a cost which is much higher than it would need to be, and many of the people who are involved in it will be not stifled but at least constrained in what they work on and how they work on it. I am quite concerned that over the next 5 to 10 years that effect is going to reduce the productivity of American science and technology.

Mr. **Walgren**. Dr. Compton.

Dr. **Compton**. May I just add a footnote to that, because I think Dr. David is absolutely correct in his assessment and drawing attention to some of the negative aspects. Let me just add that our educational system has a very, very long time constant associated with change, and if you look today at the number of vacancies that exist in our engineering faculties, the aging, the average age increasing of those faculties, the fact that a large number of our current graduate students are foreign nationals and will not remain in this country, I think one has to be concerned with the vitality of our educational system over the next decade in the higher education as well as the secondary and elementary, as was mentioned earlier. It takes a very long time to correct those problems and the question is really, as Dr. David said, will we have the talent and the people to try and accomplish what this country really wants in the area of science and technology in the next two decades?

Mr. **Walgren**. Dr. Gray.

Dr. **Gray**. Yes; I would like to echo that. I think Dr. David is right on. Although we are very optimistic about the direction that science is going, and the intellectual challenges and excitement, we are also just as concerned, as I emphasized in my testimony, about the protection of the private, the individual investigator, the importance of this and keeping that individual investigator going with his or her own research ideas.

I couldn't agree more with what Dr. David has just said, and I am also just as worried about the large—as I indicated in my testimony—about the large projects possibly squeezing out, in this point in history, the individual investigator. This would be a catastrophe for the country.

Mr. **Walgren**. Dr. Smelser.

Dr. **Smelser**. This goes back to your very first question on the optimism idea, and I would give a mixed response from my viewpoint. That is to say, from an intellectual point of view I believe that the kind of survey that we have been engaged in leaves one intellectually very optimistic because of the numbers of new lines of the creation of knowledge—the relation of brain and behavior, information science, cognitive developments, population analysis—we have a lot of them and they have shown a lot of movement.

The note of frustration that I sounded in my testimony had to do with the difficulty of pressing forward on those lines, given the present structure of our funding and, I would have to say, in some degree our educational system. I am less optimistic with regard to the continuation of the proper infrastructure for carrying out these lines of knowledge, and this includes proper replacement of our cohorts, which are also going to be vanishing in the 1990's and thereafter, and I do not see the structure of training as adequately, perhaps, reproducing and generating the next generation of people who can carry forward.

Mr. **Walgren**. Dr. Malone had mentioned that there was an age that was relatively productive in science, where someone was old enough to have developed some appreciation of related disciplines and certainly mastered their own, and yet to a certain degree we do look to the youngest of minds, don't we, for the real push into new theoretical areas? That would focus us on the age from 20 to 30 or thereabouts, not to leave anybody out of the range. But am I right in saying that there should be a real concern about the vitality of that very younger range scientists?

Dr. **Smelser**. That is absolutely correct. I think there are disciplinary differences in this regard. If you take something like history or literary criticism, you don't find such a concentration of creativity in the age as you do in some mathematics and science. We have data on this, studying the productivity of people in different disciplines, and there is quite a variation in that regard.

Some of the people who are studying the psychology of aging nowadays are beginning to revise their views about the presumed decline of mental capacity in the older years, and that the factor of wisdom is something that really begins to be another part of the—wisdom and experience becomes another part of the IQ picture that is not taken into account with your standard measures of how to classify, analyze, and so on and so forth. So I have a feeling that if you have a sufficiently broad view of theory as involving also synthetic processes as well, then that age-correlated association that you pointed out, we would change our views of it, I believe.

Mr. **Walgren**. Dr. Compton.

Dr. **Compton**. May I just point out there are two reasons for decreased productivity of the older people, and the second one—not only the one that was just discussed but the second one, and perhaps equally important—is that your more senior people are the ones who are spending a very large fraction of their time getting the money for the other people to do the research. If one could simplify that process so it was more efficient, and less time spent in that and in writing proposals, one might find a substantial improvement of productivity. [Laughter.]

Mr. **Walgren**. Well, I will take that as an urging to close at this point. [Laughter.]

Dr. **Compton**. Back to the lab.

Mr. **Walgren**. Well, on behalf of the committee, thank you all very much. We appreciate you as a resource to us, and I really feel that you have sounded a very measured alarm that should inspire us to do as best we can in the present for these areas. We appreciate your contribution to that. Thank you very much.

[Whereupon, at 4:55 p.m., the subcommittee recessed, to reconvene at the call of the Chair.]

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APPENDIX I

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

nsf
OFFICE OF THE
DIRECTOR

March 27, 1986

Honorable Doug Walgren
Chairman, Subcommittee on Science,
Research and Technology
Committee on Science and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Walgren:

Enclosed for the record are answers to the questions which you transmitted to the Foundation on March 7.

Sincerely,

Erich Bloch
Director

Enclosure

Questions Submitted For The Record By Representative Doug Walgren

LARGE-SCALE FACILITIES

Question: When do you expect the review of the organization and management of contractors who operate and manage large-scale facilities (astronomical, atmospheric, and oceanographic) will be completed? Do you have plans for similar reviews of programs managed by NSF scientists?

Answer: Proposals are being evaluated; we expect to contract for the study sometime in May. The work should be completed in January, 1987. We have no specific plans at this time for other such reviews; the information gained from the study will be used in other programs as appropriate.

NSF's major national research centers provide the entire university research community with access to large, and often unique, research facilities. Operation of the major research centers in astronomy, atmospheric research, earth sciences and ocean sciences comprises about 10% of the NSF research budget.

Question: Do you foresee growth in the national research centers in order to provide greater access and improved capabilities?

Answer: Modest growth is necessary for the national research centers to provide greater access and improved capabilities, although some improvement can be made by increasing efficiency.

Each of the National Astronomy Centers, as visitor-oriented research institutions, are constantly seeking ways to achieve this, such as:

> --Making observing with existing telescopes as efficient and "user-friendly" a process as possible through the use of electronic systems. These include systems for the control of instrumentation, the collection of observing data, and the reduction of this data to whatever form is desired for analysis. The collective effect has been to greatly increase the efficiency of observing time available to the community and to decrease the amount of time the individual astronomer must spend away from home to complete his or her observing run.
>
> --Developing and installing new instrumentation, from major new telescopes to improved designs of auxiliary instrumentation for existing telescopes. The NOAO Advanced Development Program is developing technology required for the next generation of optical telescopes while NRAO has started construction of the Very Long

Baseline Array (VLBA). The VLBA is a continent-spanning radio interferometer that will surpass all existing or planned radio telescopes in its combined resolution, sensitivity, dynamic range, mapping capability, and frequency coverage.

The National Center for Atmospheric Research (NCAR) provides computational and field measurement facilities to atmospheric and oceanographic scientists. NCAR is scheduled to install a new supercomputer in August 1986. In addition, new field measurement systems must be developed in order to proceed with two major field programs planned for the global geoscience initiative, i.e., Global Tropospheric Chemistry, and TOGA. New field measurement facilities also will be needed in the mesoscale meteorology program. NCAR's scientific visitor program must be expanded to enable university scientists greater access to improved facilities and to provide a focus for new field activities. NCAR's successful history of coordinating large, multidisciplinary field programs provides an excellent foundation for enhancing the visiting scientist program.

Because of cuts in the FY 1986 budget, many of the larger oceanographic research ships will be laid up in late CY 1986 and probably part of CY 1987. Thus, there is a near-term reduction in academic fleet ship operations; the Ocean Drilling Program lease operatives, however, will not be reduced.

Question: What are the prospects of combining the resources of the national research centers with those of individual universities? For example, could the new Keck Telescope, a privately financed Cal Tech - University of California project, be integrated into the National Optical Astronomy Observatories?

Answer: A form of sharing already exists in the presence of university telescopes on Kitt Peak, Arizona, and Cerro Tololo, Chile, both prime observing sites operated by the National Optical Astronomy Observatories (NOAO). NOAO is host on Kitt Peak to telescopes belonging to the Steward Observatory (University of Arizona), McGraw-Hill Observatory (University of Michigan, Massachusetts Institute of Technology, and Dartmouth College), and Warner and Swasey Observatory (Case Western Reserve University). NOAO operates telescopes on Cerro Tololo belonging to the University of Michigan and Yale University, respectively. The latter three instruments are available to the NOAO community of users on a part-time basis.

In the case of the Keck Telescope, the construction funds are provided to Caltech by the Keck Foundation. The University of California is to provide operating funds for several years until its contribution is equal to the amount provided for construction. The Keck Telescope can easily be fully utilized by astronomers from the participating institutions.

At NCAR, prospects for combining resources are very good. In fact, some efforts are already underway. For example, the NSF supercomputer centers are in the process of being networked via ARPANET, a terrestrial NSF backbone network, and satellite communications. NCAR will be a node on these networks. Connection of universities to these networks will be done through an interface with the campus Local Area Network. This configuration will allow scientists to use synergistically both local and remote computing resources to maximize their productivity. An additional example is the UNIDATA Project which is managed by the University Corporation for Atmospheric Research (UCAR). The goal of this project is to disseminate scientific data from national centers and provide the university community an interactive capability for retrieving, examining and using these data. The university community has been involved with this project from its inception.

Options for ship operating economies through further combining of facility operations are being investigated. Plans for ship lay-ups are being coordinated through the University-National Oceanographic Laboratory System (UNOLS) community and with other Federal agencies, especially Office of Naval Research (ONR).

GLOBAL GEOSCIENCES PROGRAM

Question: Data management appears to be a major component of a successful global geosciences program. How will NSF and related agencies focus on, and give priority to, data management needs to assure the maximum benefit from the research investment?

Answer: In the case of the Global Seismic Network, a research data center and a network for data collection and dissemination are an integral part of plans developed by Incorporated Research Institutions for Seismology (IRIS). The IRIS Data Management Center will begin operations, on a small scale, in FY 1986. Effective dissemination of digital seismic data in convenient form to research seismologists is a high priority.

The planning for the Global Tropospheric Chemistry Program (GTCP) component of the Global Geosciences Program (GGP) has been done, thus far, by a panel of the National Academy of Sciences' Board on Atmospheric Science and Climate. That panel was formed at the request of NSF, subsequently joined in sponsorship by NASA. Scientists from NOAA and other agencies have been involved in the development of the plans. The research scientists on this panel consider the data management aspects of the plans as vital to the success of the program. The data management model that is being considered initially is comparable to the one used by the successful international Global Atmospheric Research Program (GARP). The Subcommittee on Atmospheric Research (SAR) of the Committee on Atmosphere and Oceans of the Federal Coordinating

Council for Science, Engineering and Technology has appointed an interagency panel for coordinating the GTCP. The panel has designated data management planning a high priority responsibility.

Much of the coordination and planning for the Tropical Ocean Global Atmosphere (TOGA) component of the GGP is carried out by the U.S. TOGA Project Office and the NAS TOGA Panel. NSF and NOAA have been working closely with these two elements to develop national data needs and data management strategies. Through the World Climate Research Program Office in Geneva, the U.S. data plans are coordinated with the international TOGA data management activities.

The Ocean Sciences (OCE) subactivity has a long-standing data management policy to ensure that large comprehensive data sets are properly achieved, mostly using NOAA-run archives. This policy has been updated and will continue to be routinely distributed to ocean scientists supported by NSF grants.

The Global Ecosystems Dynamics component of this program builds upon NSF's series of projects investigating long-term phenomena in diverse ecosystem types. Because these existing projects deal with long-term research questions, the investigation of which could extend beyond the tenure, even the career, of an individual scientist, considerable effort (intellectual and operational) has been directed toward data management (see for example a recent, major symposium volume, Research Data Management in the Ecological Sciences, edited by Wm. K. Michener, University South Carolina Press). Data management is an evolving field and it will be expected that projects in the global ecosystems component will continue to work at and advance the state-of-the-art. More recently, projects are seeking ways of rapid data exchange using various commercial data networks. Existing projects also are cooperating with NASA (working sessions scheduled in the early fall of 1986) to learn how to access, exchange, and use remotely sensed data. Data management of large, integrated, long-term programs is viewed to have importance in tandem with that of scientific objectives.

Question: What strategies will the Foundation use to broaden the participation and support for the global geosciences program from the international community, particularly financial support in accomplishing the long-range goals of the global geoscience program?

Answer: The Foundation considers international participation and support to be an essential element in the program. Fortunately, international groups such as the International Council of Scientific Unions (ICSU) have already strongly endorsed many elements of the program and many countries have already begun activities in support of it.

In the solid-earth sciences, the International Lithosphere

Program incorporates many of the aims of Global Geosciences. Several nations including France, Canada, and the Federal Republic of Germany have already begun, or announced their intention to begin, the establishment of national digital seismic networks. Efforts are underway internationally to ensure that the instrumentation for these networks is mutually compatible and that provision is made for maximum and easy exchange of seismological data. The existence of these national networks significantly reduces the number of U.S. stations required to achieve optimal global coverage and will permit optimum use of U.S. research funds.

Other large-scale international projects that will integrate with and contribute to U.S. efforts in the earth sciences include the European Geotraverse, the Canadian Lithoprobe project, the British BIRPS program, the German DECORP program, and others. Exchange of data and personnel between these projects and U.S. funded projects in global geosciences is already occurring.

The Foundation has begun to implement the following strategies--NSF has begun discussions with the National Academy of Sciences' Board on Atmospheric Science and Climate (BASC) on steps to be taken to develop international scientific participation in the Global Tropospheric Chemistry Program (GTCP) portion of the Global Geosciences Program. It is anticipated that ultimately the International Council of Scientific Unions (ICSU) will be the scientific coordinating mechanism for international participation. NSF has made a presentation on the GTCP to the European Science Foundation (ESF). The response indicated ESF was enthusiastic about participation and support. NSF and NOAA are presently discussing bilateral agreements with the People's Republic of China (PRC) that include GTCP activities. The PRC response has been positive. NASA has developed bilateral agreements on GTCP related activities with several South American nations. NSF representatives have also begun informal discussions with appropriate government counterparts in various western European nations.

NSF augments its TOGA activities internationally through the World Climate Research Program under the aegis of the World Meteorological Organization, the International Council of Scientific Unions and the International Oceanographic Commission. An intergovernmental commitments meeting for TOGA will be held in May 1986. At that time, the participating nations will commit the resources necessary to carry out the operations, data collection, data management and research. NSF is working closely with NOAA to prepare for this meeting.

OCE is continuing to work with its counterpart science-supporting agencies in other countries, primarily in U.K. France, FRG, and Japan to involve their scientists and facilities in projects included within the Global Geosciences Program. Copies of the OCE Long Range Plan for Ocean Sciences have been widely distributed among scientists in all these countries and OCE staff members have visited scientists and their funding institutions to brief them on the program.

As an example of the level of interest, the UK's Natural Environmental Research Council hosted a meeting at the Royal Academy of Sciences in London on 4 February to begin planning the involvement of UK oceanographers in the study of the Global Ocean Fluxes, a key component in the studies of the world ocean. A follow-on meeting involving scientists from several countries is scheduled to be held at the University of Maryland's Horn Point Laboratories on 17 March to continue these international planning activities.

These planning activities include participation of scientists and joint ship operations to study these processes on a planetary scale.

MATHEMATICS

Question: Given that mission-oriented research agencies have generally focused their support on applied mathematics and statistics, and that the National Science Foundation's goal is to promote the broad spectrum of the mathematical sciences, why do the subactivities of Applied Mathematics and Statistics and Probability receive the largest percentage increase for FY 1987?

Answer: There are important differences between the research in Applied Mathematics and Statistics supported by the NSF and that supported by mission agencies. NSF programs provide support for research on a broad range of topics. Potential application is considered a possible source of motivation for NSF proposals but is not necessarily a short term goal. By contrast, the mission agencies emphasize more immediate goals dictated by short term considerations, and concentrate on well focused, often narrowly defined topics.

It is primarily in the programs of Applied Mathematics and Statistics and Probability that the Foundation supports numerical analysts, computational statisticians and other mathematical scientists who are doing fundamental work in the development of computational methods to solve problems that arise in science and engineering. The larger budget increases in these programs are primarily a reflection of our expectation that mathematical scientists whose research is supported in these areas will play a significant role in the initiation of the thrust in computational science and engineering. The Rheinboldt Report, instrumental in describing both the opportunities in computational science and engineering and new modes for taking advantage of them through interdisciplinary teams, was generated by the applied mathematics community in collaboration with statisticians, mathematicians with more theoretical orientations, and computer scientists. As indicated in the original budget submission, funds associated with this computational initiative will be coordinated on a

Subactivity-wide basis with the development of multidisciplinary teams providing a focus for the research supported. When this is taken into consideration, the increase for base activity in both the Applied Mathematics and Statistics and Probability programs is comparable to that of the other programs.

It is true that Applied Mathematics and Statistics receive much greater support from the mission-oriented agencies than do the other subactivities in the Division. It is also true that the need for increased support is keenly felt in all areas of the mathematical sciences. We are faced with a conflict between perceived immediate opportunities in the computational areas of the mathematical sciences, and the longer range goal of supporting the broad spectrum of the discipline. Of course neither can be ignored. It is felt that the proposed budget strikes a proper balance between these conflicting goals.

Question: What attempts are being made to stimulate young investigator research, through such mechanisms as the Presidential Young Investigator Program, the Research Opportunities for Women Program, in disciplines such as mathematics where declines in manpower have been cited as critical?

Answer: The Mathematical Sciences Subactivity has taken every opportunity available to it to stimulate research of young investigators and improve the ability of the field to attract strong young scientists. There have been dramatic increases in the number of graduate students and postdoctoral researchers supported on NSF grants in the mathematical sciences over the last five years.

The Presidential Young Investigator program has been exploited by mathematical scientists. There have been a number of high-quality nominees during the three years of this program's existence. The program is somewhat more attractive to researchers in applied mathematics and statistics where matching money is more readily available than in the more theoretical aspects of the mathematical sciences. We are working to encourage more nominations of outstanding mathematical scientists from all branches of the field.

The Mathematical Sciences Subactivity has made great progress in encouraging the participation of women in its programs. There has been a significant increase in the number of women, particulary those in the earlier stages of their careers, whose research is being supported by the subactivity. Some of these applied through the ROW program; others are supported as principal investigators by the Subactivity. In addition, the Subactivity has split-funded a number of awards under the Visiting Professorships for Women program, ensuring that the largest number of role models would be available for young women entering the field.

In a related area, the staff of Mathematical Sciences has begun working closely with the staff of the Minority Research Initiation program. Our goal is to ensure not only that minority researchers of high quality receive support for their research but also that the support provided is as beneficial as possible in overcoming barriers to full participation in research careers.

SOCIAL SCIENCES

Question: A witness at our authorization hearings testified that some programs in the Social and Economic Sciences Division are placing caps on the amount of each grant. If this policy is indeed followed, please explain why. Is this fixed upper limit on grant size followed in other disciplines, other divisions of BBS, or other Directorates?

Answer: There are no caps on grant sizes in any of the programs in any BBS division, including the Division of Social and Economic Sciences (SES). However, SES program officers are responding to budget stringency and cuts imposed by the Gramm-Rudman-Hollings legislation by examining all grant budgets very closely (see NSF Important Notice No. 100). SES awards are limited in size to the absolute minimum necessary to accomplish the work NSF is most interested in supporting, which often is a portion of, rather than the entire, project proposed.

Question: The National Academy of Sciences' ten-year outlook on research opportunities and priorities in the behavioral and social sciences, presently underway, is expected to identify several new initiatives and priorities for these sciences. Will the NSF's stringent budget in this area allow for implementation of such recommendations for the behavioral and social sciences?

Answer: NSF has maintained frequent contact with the NRC Committee on Basic Research in the Social and Behavioral Sciences. We have been the major supporter of the ten-year outlook study, and we have had the benefit of examining some of the Committee's working papers in draft form. As a consequence, some of the topics and issues highlighted in those working papers are already areas of social and behavioral science emphasis in the FY 1987 budget request--e.g., research on the biological factors underlying learning and memory; examination of the roles of organizations in social behavior; and increased efforts toward infrastructure development in these fields. The Committee, however, has not yet finished its work, and therefore no related larger-scale emphases or initiatives could have been built into the FY 1987 request. Since the Committee will be completing its work at the same time that NSF is developing the details of the FY 1988 budget requests, we expect the impacts from the Committee's recommendations will be felt more heavily in that year than in FY 1987.

UNIVERSITY RESEARCH FACILITIES NEEDS

The NSF Authorization Act of 1986 authorized the establishment of a data collection capability to identify and assess the research facilities needs of universities, by major field of science and engineering. The provision calls for surveys every two years with the results reported to Congress, the first report due September 1, 1986.

We understand that in the pre-test for the first survey, the behavioral and social sciences were not included in the fields of science surveyed.

Question: Do you intend to include these sciences in the surveys that are reported to Congress?

Answer: The National Science Foundation has submitted for clearance by the Federal Educational Data Acquisition Council (FEDAC) the questionnaire that will be used to collect data on research facilities from 170 of the Nation's leading research universities which will form the basis for the report due Congress on September 1, 1986. This questionnaire is designed to obtain on a rapid response basis aggregate data on facilities for all fields of science and engineering, including the behavioral and social sciences.

Planning is underway for a full-scale survey to be conducted in Fiscal Years 1987-88 and biennially thereafter that will obtain information on research facilities in academia by major fields of science and engineering, again including the behavioral and social sciences. The institutional coverage will be expanded to include nationally representative data for doctorate-granting universities, undergraduate and historically black institutions.

STIA/MINORITY CENTERS OF EXCELLENCE

Our Committee supports the efforts of the National Science Foundation in its attempts to broaden participation in science and engineering among women and minority groups. As a consequence, we are very interested in the proposed Minority Centers of Excellence. With their establishment however, two concerns arise:

Question: Given the limited number of Minority Centers of Excellence which are to be established, do you feel that such institutional support is the most effective way to mainstream the individual minority students into the American science community?

Answer: Institutions with predominantly minority faculty and student enrollments are playing a large and increasingly important role in the conduct of scientific and engineering research by minority investigators and in the preparation of minority students for research careers. The proposed Minority

Research Centers of Excellence (MRCE's) will be located in areas where there are large numbers of minority students. They will strengthen the research and training capacities of a selected number of these institutions, and help them attract and retain outstanding faculty researchers, graduate students and undergraduates, establish cooperative research projects and other links with major research centers, develop new and innovative research programs, and provide assistance and support for research and educational programs at other, less advanced minority institutions in their regions.

The MRCE's would represent only a small part of the overall effort needed to bring more individual minority students into the mainstream of the American scientific community. It would, nevertheless, be a very effective means for enhancing the institutional capabilities in science and engineering for universities serving significant numbers of minority students. Because of the outreach educational activities with neighboring colleges and schools that would be generated by these centers, their actual impact would reach far beyond the confines of the individual center campuses.

Other NSF programs address other related aspects of this general problem. Minority Research Initiation, for example, seeks to make it easier for minority investigators to receive their first NSF grants, thus helping them to enter the main stream of Federal research support. Research Improvement in Minority Institutions (RIMI) provides relatively small awards (up to $300,000 over three years) to improve the research and training capacities of a much larger group of institutions with substantial minority enrollments. Awards made by the Science and Engineering Education Directorate are aimed at improving the quality of education available to minority students of science and engineering. All of these approaches are necessary and complementary, and we believe that the proposed MRCEs are currently the most effective use of additional resources in this area of concern.

Question: A related question addresses the same issue from a management perspective. How will the design of Minority Centers of Excellence be coordinated with existing National Science Foundation programs for minorities namely, Minority Research Initiation and Research Improvement in Minority Institutions?

Answer: The proposed MRCE's will be located in the same division (Research Initiation and Improvement) and under the same management as MRI and RIMI. This will provide both coordination and flexibility in the administration of these programs, to ensure that in their different ways, they all contribute to the achievement of our goals.

SCIENCE AND ENGINEERING EDUCTION (SEE)

The entire increase for Science and Engineering Education ($2 million) is concentrated in the College Science Instrumentation Program (CSIP).

Question: Strengthening engineering laboratories in the nations's colleges and universities is mentioned as a CSIP target, as well as continuing to strengthen laboratory instruction at four-year colleges. Will two-year, or community colleges be eligible for CSIP funding?

Answer: The requested increase of $2 million for the College Science Instrumentation Program in FY 87 will permit the Foundation to extend eligibility in this program to engineering departments and institutions which currently are not eligible to participate in the program. For engineering only, eligibility criteria would be modified to include all colleges and universities. The program will thus greatly extend its impact in the engineering fields, where instrumentations needs are particularly severe.

This sum cannot, however, be stretched to cover the 1,286 two-year (community) colleges. CSIP is at present able to issue only one award for every five to six proposals (~ 19% success). To provide such schools a reasonable opportunity to benefit from CSIP would require a funding increase very substantially greater than the one contained in the Foundation's current budget request.

It is estimated that there are over one million computers for instructional purposes in secondary schools. In a National Education Association (NEA) survey, about 50% of all software assessed by teachers failed to meet NEA's minimum certification standards.

QUESTION: What is NSF's role in motivating the development of quality software so the expensive hardware does not lose much of its intrinsic worth?

ANSWER: We recognize a need to assist educators who are attempting to exploit the enormous potential of technology to revolutionalize science and engineering education. While we cannot support even a small fraction of the ongoing computer software development, we do support research and development activities that focus on highly innovative devices and promising but untested methods of introducing technology into educational settings.

QUESTION: What percent of the Materials Development, Research and Informal Science Education within SEE will be allocated to the Applications of Advanced Technologies Program (software) in FY 86 and FY 87?

ANSWER: In both FY 86 and FY 87 $5,000,000 or 20% of the Materials Development, Research and Informal Science Education Division funds will be allocated to the Application of Advanced Technologies Program. In addition, through other programs in SEE, support is provided for the effective use of advanced technologies in precollege science and mathematics education.

QUESTION: Are the allocation of funds for Application of Advanced Technologies more or less than expended in FY 85 and why?

ANSWER: Less. The funds expended by the Advanced Technologies Program in FY 1985 were $7,545,692. However, the FY 86 budget for Advanced Technologies was not so much a reduction from an established level of expenditures as it was a return to normal after a planned one year of abnormally high expenditures for this program. The actual figures reveal the situation:

Advanced Technologies Program

Actual Expenditures	FY 84	$1,437,837
Actual Expenditures	FY 85	$7,545,692
Current Plan	FY 86	$5,000,000

In evaluating the adequacy of NSF support for the introduction of technology into the classroom, one should recognize that about one-third of the projects supported under the instructional materials development program involve the development of computer software. We choose to focus the advanced technologies program on cutting edge research and development and to assign projects that support applications of developed technologies to the materials development program. Thus to estimate NSF support for educational technology one should add one-third of the materials development budget to the advanced technologies budget. This calculation is exhibited below for recent years.

	Actual FY 84	Actual FY 85	Current Plan FY 86	Estimate FY 87
Materials Development	13,219,006*	5,982,122	8,500,000	8,500,000
1/3 of Materials Development	4,406,335	1,994,041	2,833,333	2,833,333
Advanced Technologies	1,437,837	7,545,692	5,000,000	5,000,000
Support-Advanced Technologies, Total	5,844,172	9,539,733	7,833,333	7,833,333

*A large fraction of this amount was carryover funds from FY 1983.

FUNDAMENTAL RESEARCH FOR EMERGING AND CRITICAL ENGINEERING SYSTEMS

Question: What have been the benefits, if any, in combining the Bioengineering and Research for the Handicapped Programs?

Answer: The Bioengineering and Research for the Handicapped Programs have been combined in the sense that they are administered by a single and highly qualified program director, thus reducing the costs of administration it. Separate budgets are maintained, one for each program.

The benefits that are hoped for in this arrangement would be the ability of the single program director to recognize advances in bioengineering knowledge that could be applied to the Research for the Handicapped Program. Conversely he would be in a good position to recognize the needs for advances in fundamental bioengineering knowledge that would arise from the Research for the Handicapped Program. In both cases, the single program director would be in a unique position to take appropriate action to bring about a beneficial cross-fertilization.

An example of the bioengineering knowledge base leading to a major advance in research to aid the handicapped has been in the area of biological signal analysis. Recent advances in signal processing have stimulated research into speech recognition by computer. This will allow telecommunication possibilities for groups of disabled people who previously have not been able to communicate across long distances. Conversely, the research on speech recognition for the disabled has led to bioengineering research into speech recognition when speech is corrupted by a person's disability or, more generally, by noise on transmission lines.

ADVANCED SCIENTIFIC COMPUTING (ASC)

We are pleased NSF is beginning to develop a computer network.

Question: How do you plan to support the infrastructure for an effective national computer network?

Answer: The NSF plans to develop the national computer network (NSFnet) in two phases. In the first phase, NSFnet will be developed by taking advantage of existing community and consortia networks (ARPANET, the SDSC network, the JVNC network); by installing a backbone network between the supercomputer centers (initially at 56 Kbit/sec, and later at 1.544 Mbit/sec as traffic demand increases) to ensure that users on any of the center or consortia networks can get access to all the NSF supercomputer centers; and by supporting and encouraging the development of regional and state-wide networks conforming to the NSFnet model and standards.

The approach is to build a network of networks or "Internet." As part of this phase a Program Announcement will be released encouraging research universities to make proposals for funds to connect their campus networks to one of the component networks in the NSFnet.

In the second phase, NSFnet will be expanded by expanding the Backbone network, by upgrading the Bandwidth of the component networks, as required, to support high-speed (megabyte/sec or greater) access to remote computing resources from advanced graphics workstations. In addition, an overall management structure will be developed to ensure that the national network infrastructure is a stable and reliable service for the U.S. research community.

In addition to the NSF's plans for a national computer network, discussions are also being held with other Federal agencies dealing with supercomputers, e.g. NASA, DARPA, DOE and NIH, to connect all government supported networks together through gateway systems.

Question: In the long-range will a management contract be necessary to service the network users, maintain the network, allocate computer access time, and coordinate the efforts of the NSF national computing centers?

Answer: We feel that it is essential that a network manager be found to provide the level of expert service to the users which cannot be provided by NSF staff. We will issue a solicitation to request proposals for a network management contract in the near future. This contract will pertain only to network management and maintenance and not to other supercomputer management functions. Computer access will continue to be managed by the demand from peer reviewed proposals of NSF grantees and from direct requests to the centers. In the latter case, special *ad hoc* allocations committees have been established for each center to review all requests made directly to the centers. Peer review of proposed usage is paramount. Computer center coordination will continue be conducted by NSF and to various advisory and review committees.

Question: To what extent are other federal agencies participating in the design and funding of the network NSF is planning?

Answer: At the present time, other agencies are not participating in the design and funding of NSFnet. However, NSF is working with other agencies to develop NSFnet: In particular NSF and DARPA have signed a Memorandum of Agreement (MOA) under which DARPA will expand the ARPANET to connect to NSF selected sites, and NSF will transfer $2.0M per annum to DARPA.

In addition, discussions are under way with NASA NAS at NASA-AMES to allow NSF supercomputer users access to the NASA NAS CRAY 2 system, in return for which NSF will connect the NASA NAS systems to NSFnet. Discussions are currently underway with other agencies through the supercomputer subcommittee of FCCSET to develop a coordinated approach to the development of a National Interagency Research Network. The FCCSET approach will coordinate the funding of the interconnect of the agency networks but the design and funding of individual agency networks such as NSFnet will remain the agencies' responsibility.

Question: Do you have plans to evaluate the productivity and attributes of the NSF computing centers?

Answer We plan a major review of all of the national centers during the summer of 1986. As a part of this review, productivity and quality of service will be thoroughly examined. Review teams consisting of NSF staff, members of the Program Advisory Committee, members of the Technical Review Groups, software and hardware experts and consultants, computer center directors (other than the NSF supercomputer center directors), etc. are currently being formed to conduct this review. Several categories of criteria for evaluation of the centers will be imposed. These include: scientific impact, services provided, management, and training/consulting, productivity, efficiency, scientific breakthrough, user-friendliness, access, technological advance development in hardware and software, and assistance in code development.

Question: To what extent does NSF fund research to develop network technology or pilot network projects?

Answer: As part of our plan to develop the national network, we expect to fund a small number of pilot projects in FY 86/87 to test new network technology. In 1985, we started one such project which will connect the supercomputer center at NCAR to six research institutions by means of satellite connections.

Projects which might take place in FY 87 include.

- High-speed (T1 or greater) terrestrial links between supercomputer centers and user campuses using optical fiber technology. An objective will be to explore the development of high performance networking protocols. ($1 million per annum).
- High-speed (10 MBit/sec) satellite broadcast system based at a supercomputer center utilizing a high-power large scale hub antenna and very small (1.5 meter) remote

site antennae at the campuses. An objective will be to explore the use of broadcast systems to transmit graphics images to remote workstations ($1.0 million per annum).

- Participation in the Wideband Satellite project currently supported by DARPA. NSF would join that pilot project by placing an earth station at one of the current supercomputer centers and use very high-speed connections (6 million bits per second) with other Wideband sites currently located near other centers. The objective will be to create a high-speed satellite based backbone network between several of the centers and major concentrations of user campuses ($0.5 million per year).

Question: Why hasn't NSF opted for continued support for the unique supercomputer capacity at the University of Minnesota? Has NSF any plans for involving the Cray 2 at the University of Minnesota in the Phase 2 plan?

Answer: The University of Minnesota supercomputer center is currently supported by the NSF advanced scientific computing program, at a level of about $3 million per year, to provide supercomputing services for the U.S. academic research community. This grant was started in 1984 through the interim resource center program (often referred to as Phase I Centers) and will continue through to the end of FY 1986.

In FY 1987 we plan to continue the resource center program at a level of about $2.3 million in providing services not available at our national centers. An announcement of this program will be issued soon. The University of Minnesota (as well as any other facility) may respond to this new activity and any new solicitation for additional Phase 2 centers.

NATIONAL SCIENCE BOARD (NSB)

Question: What was the role of the National Science Board in setting priorities and budget levels for FY 87?

Answer: The National Science Board played a central policy role in establishing priorities and levels for the National Science Foundation's budget request for FY87. The Board's Executive Committee and Committee on Budget were directly involved in the Foundation's planning process for the budget. The full Board spent virtually the entire June meeting in examining the Foundation's goals and implementation strategies under alternative resource scenarios as presented by the director and senior Foundation staff. The Board's Committees were especially active over the summer, working closely with the

Director on the details of the proposed budget.

At its August meeting, the full Board unanimously accepted the report and recommendations of the Committee on Budget, and authorized the Director to submit the budget request to the Office of Management and Budget. The Board was kept apprised of the many subsequent discussions between the Foundation, the Office of Science and Technology Policy, and the Office of Management and Budget, and is fully supportive of the President's request now pending before the Congress for the funding of the National Science Foundation's activities in FY 87.

Question: In setting research and program priorities, what weight do you give to: 1) the "readiness" of a discipline to address a research problem; 2) breadth of participation by multi-disciplines; 3) opportunities for geographic distribution?

Answer: Many factors are taken into consideration in constructing the budget proposal for the National Science Foundation. Resources are always in scarce supply relative to the opportunities for investments. The Director and the Board are constantly striving for appropriate balances among the many worthy competitors for funding support. While it is difficult to construct precise weights for the various factors which must be taken into account, the"readiness" issue in particular was a major part of the National Science Board's review of the needs and opportunities of scientific disciplines.

The increasingly multidisciplinary nature of many fields of research was also recognized and reflected especially in the request for support for the proposed emphasis in Biotechnology, Global Geosciences, and Computational Science and Engineering.

Geographic distribution on the other hand is more directly addressed in the proposal and award management phase of Foundation activities -- that is to say, the budget execution rather than the budget formulation process. However, the Board has always been cognizant of the statutory requirement to "avoid undue concentration". The request for continued support of the Experimental Program to Stimulate Competitive Research is not the only but perhaps is the most direct responsive element to this requirement in the Foundation's budget proposed to the Congress.

NATIONAL SCIENCE WEEK

Question: Please summarize the Foundations's Science Week activities for 1985. What plans does the Foundation have for Science Week in the future?

Answer: The first National Science Week took place May 12-18, 1985. During that time, programs and activities designed to enhance public understanding and awareness of science and technology were held in communities across the nation, including all fifty states and the territory of Guam. Nearly 1,000 local, state and national groups participated. Events included special science and math competitions, open house events at research facilities, teacher workshop and recognition programs, science fairs, and lectures, museum exhibits and a variety of media events. Public Service Announcements (PSAs) were produced by prominent spokes people such as Don Herbert (TV's Mr. Wizard) and Sally Ride and aired on national television; articles were carried by newspapers, magazines and professional journals.

To most effectively concentrate resources and track the success of National Science Week in this first year, ten target cities were chosen for special efforts, based on their geographic spread and the presence of a key contact organization. A summary of their activities are as follows:

SEATTLE - Seattle's Museum of Flight helped sponsor a design competition called the Second Great International Paper Airplane Contest.

PHILADELPHIA - A unique approach here was the National Dinosaur Short Story/Essay Contest sponsored by the Academy of Natural Sciences. Students from grades 1 to 12 entered short stories and essays on almost every type of dinosaur known. Winners were announced as part of an NSW lecture on dinosaurs at the National Geographic Society, Washington, DC. Noted paleobiologist Jack Horner, an NSF grantee, gave the lecture.

PITTSBURGH - The Carnegie Institution's Regional Center for Science Teachers hosted a full week of events, among them an awards dinner and a science education panel involving local educators. Riverside workshops for students included experiments in water analysis, pollution control, and freshwater biology.

MILWAUKEE - This city sponsored one of the Week's largest Science Fairs: "SCI-A-RAMA," hosted by the Milwaukee Public Museum involving 10 local schools, and aided by local media coverage.

CHICAGO - In a joint program with the Museum of Science and Industry, Columbia College organized lab and nature tours and showed science videotapes and presentations to students and teachers. Abbott Laboratories and Sigma Xi, the honor society for scientists, planned student essay contests, an "open house" at research facilities, and teaching workshops.

SALT LAKE - The University of Utah and the Terra Technology Company hosted a week-long agenda for students, teachers, and the general public. Events included planetarium displays, magic shows by the university's chemistry department, and demonstrations of aircraft and aerodynamics through flight simulatore.

NEW YORK - The New York Academy of Sciences adapted its successful "Scientists in Schools" outreach program to National Science Week, involving 200 member scientists.

Washington, DC's Benjamin Banneker High School (named for the noted Black scientists and inventor of the Revolutionary era) held a paper airplane contest - a smaller version of the event in Seattle.

Finally, honoring National Science Week from outer space, Senator Jake Garn (R-UT) flew a paper airplane aboard the space shuttle CHALLENGER as part of the "Toys in Space" program. The paper airplane carried the NSW symbol and is now exhibited at the Smithsonian Air and Space Museum.

For 1986, plans are in place for Science Week during the week of May 11-17. Major plans include the development of multidisciplinary activity packets for use by 12,000 elementary and junior high school students throughout the country, compiled with the help of professional, education and scientific organizations, and the production and dissemination of publications and materials to aid grassroots involvement. Again, activities will occur all across the nation, with special events being planned for Washington, DC.

APPENDIX II

American Chemical Society

OFFICE OF THE
PRESIDENT

George C. Pimentel
President-Elect, 1985
President, 1986
Immediate Past President, 1987

1155 SIXTEENTH STREET, N.W.
WASHINGTON, D.C. 20036
Phone (202) 872-4600

March 14, 1986

The Honorable Doug Walgren
Chairman
Subcommittee on Science, Research and Technology
Committee on Science and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

As the world's largest scientific society dedicated to a single discipline, the American Chemical Society offers the following observations on the Administration's budget request for the National Science Foundation for FY 1987. These comments will focus primarily on research in the chemical sciences.

The NSF Organic Act directs the Foundation to initiate and support basic research and education programs at all levels. The Foundation's importance to the scientific research and education enterprise in the U.S. is beyond dispute. NSF bears the major responsibility for maintaining the health of basic scientific research in the U.S. It accounts for about 28 percent of federal support for basic research in academic institutions and maintains U.S. scientific strength by funding research in all fields of science and engineering. It is in the best interest of the country for Congress to fund the NSF at least at the level proposed by the Administration for FY 1987. Under this proposal, support for Research and Related Activities would increase from the FY 1986 Gramm-Rudman-Hollings figure of $1,294.1 million to a total of $1,479.0 million in FY 1987, representing an increase of $184.9 million or 14.3 percent.

While many features unite the various scientific disciplines, these disciplines differ in their organizational patterns and in their top-priority research needs. For example, in high energy physics, an accelerator may hold the key to progress; in astronomy, a large telescope may be central to future advancement. Progress in chemistry today arises from a significant number of small but well-equipped laboratories.

What happens in these laboratories is very important to societal needs and for the economic competitiveness of this Nation. Due to its nature, chemistry inherently makes contributions to our national progress that are most impressive. Our entire physical world is made of material that lends itself to preservation, substitution, and transformation. These activities are carried out through chemical science and technology. Most scientific disciplines, ranging from molecular biology to astronomy, make use of chemistry. A large number of industries use chemistry in the manufacture of their products. The routine analytical sciences which support the nation's health systems use chemistry. Chemistry is truly a pervasive science.

The recently published National Academy of Sciences/National Research Council (NAS/NRC) Report, *Opportunities in Chemistry*, details how advances in the chemical sciences can be the key to future progress leading to new processes and materials, more energy and food, a cleaner environment, and better health for the citizens of the world. These advances are dependent upon ideas and experimental results emanating from basic research studies.

The support of the National Science Foundation is essential to the vitality of the research base residing in our academic institutions. In fiscal year 1984, NSF provided 47 percent of the federal obligations for basic research in chemistry performed by universities and colleges; most of this support was contributed by the NSF Chemistry Division.

The American Chemical Society endorses the recommendation of the NAS/NRC Report that states that the NSF Chemistry Division budget should be doubled over a three-year period. The Society likewise endorses the following emphases in the FY 1987 request for the NSF Chemistry Division:

- Initiation of a five-year plan in shared instrumentation to fund ongoing maintenance and operations support associated with new instruments, and increased allocations for dedicated instruments in FY 1987. The ACS, as well as the NAS/NRC Report, recommends that annual operating and maintenance costs be built into the NSF shared instrumentation program, and that funds for dedicated instruments be increased. In addition, there is an initiative in computational chemistry. The ACS supports this initiative which will effectively integrate use of computers by researchers.
- Support for collaborative research activities in materials chemistry, chemical catalysis, and development of new modern instruments, as well as collaborative and individual investigator projects in the chemical underpinnings of biotechnology. These research areas are among the fields of study which the Academy Report identified as providing opportunities for significant intellectual advancement that will also help yield social and economic returns for the United States.
- Increase of the average grant size in FY 1987 over the FY 1986 figure.

While the overall increase of 17.6 percent above the FY 1986 Gramm-Rudman-Hollings figure in the Chemistry Division's budget is healthy, it falls short of the 25 percent increase recommended in the Academy Report. Nevertheless, it is an important step in the right direction that must be preserved in the FY 1987 budget process, and maintained in future fiscal years. The ACS urges Congress to support this requested increase in chemistry, which is small when compared to the potential benefits to the economy and our society as a whole.

The ACS believes that as a nation we must insure that the human resources needed by our industries are well-trained and educated. The Foundation is the lead federal agency that attends to the overall health of the academic support structures that produce the Nation's scientific and engineering manpower. Without this continued NSF support, the Nation will be deferring the training of numbers of scientists and engineers who are critically needed by U.S. industry. Chemistry is an especially crucial area since chemists make up the bulk of physical scientists employed by U.S. businesses. Our other major comments on the NSF FY 1987 request focus on this support structure and are summarized as follows:

- The American Chemical Society notes that the Directorate for Science and Engineering Education will surely require a larger expenditure of funds in future years to accomplish its overall goals. The Foundation is to be commended for its programs in the K-12 areas; however, new programs are needed at the undergraduate level where future scientists and engineers receive their education.

- The Society is pleased that NSF is proceeding with a study of the need for new or renovated scientific facilities. The ACS supports a competitive, merit-based peer-review process. Such a process must be the primary mechanism for selection of proposals for large-scale research centers and facilities, as well as for the selection of proposals for research and instrumentation designated for them.

- There is broad recognition that continued productive communications between U.S. scientists and scientists in other countries are important to economic development. The ACS supports the FY 1987 budget request for International Activities, but regrets that the Foundation does not seem to have sufficient resources to add new cooperative research activities.

- The Foundation is to be applauded for its programs that enhance the participation of underrepresented groups or institutions in research activity and that improve the Nation's scientific and engineering infrastructure. The ACS is pleased that Presidential Young Investigators, Visiting Professorships for Women, Research Opportunities for Women, Support for Predominantly Undergraduate Institutions, Minority Research Initiation, and Research Improvement in Minority Institutions are among those programs with a continued funding commitment.

In conclusion, the ACS is heartened to see that the importance of basic chemical research and of education is stressed in the Foundation's budget request. The Society urges Congress to continue support for these areas at a time of fiscal restraint.

Sincerely yours,

Geo C. Pimentel

George C. Pimentel

cc: Other Members, House Science and Technology
Subcommittee on Science, Research and Technology

American
Psychological
Association

STATEMENT OF

Leonard D. Goodstein, Ph.D.

Executive Officer

American Psychological Association

on behalf of

THE AMERICAN PSYCHOLOGICAL ASSOCIATION

before the

UNITED STATES HOUSE OF REPRESENTATIVES

Subcommittee on Science, Research and Technology

Committee on Science and Technology

on the subject of

NATIONAL SCIENCE FOUNDATION AUTHORIZATION

Fiscal Year 1987

March 26, 1986

The Honorable Doug Walgren, Chairman

1200 Seventeenth St. N.W.
Washington, D.C. [illegible]
[illegible]

Mr. Chairman and Members of the Subcommittee, I am Dr. Leonard D. Goodstein, Executive Officer of the American Psychological Association (APA). Thank you for this opportunity to submit our views on the authorization of the National Science Foundation (NSF) for Fiscal Year 1987. APA represents the concerns of more than 76,000 psychologists, many of whom conduct important research with the support of NSF.

In this statement we will address specific areas of the proposed Fiscal Year 1987 NSF authorization of interest to behavioral and social scientists. We will then comment at some greater length on an area of great concern to this Committee, the Administration and concerned Americans: the revitalization of this nation's economic and technological base.

NSF FISCAL YEAR 1987 REAUTHORIZATION

APA appreciates this opportunity to strongly endorse the Administration's proposed Fiscal Year 1987 research budget for the National Science Foundation. We commend the President and NSF Director Erich Bloch for proposing that NSF's authorization be raised to $1.7 billion even in this time of the most urgent fiscal austerity. These increases have been proposed by the Administration because of its conviction that investing in basic scientific research will improve our competitiveness abroad and our scientific base at home. APA is in agreement with that assessment of the importance of basic scientific research and strongly supports the President's Fiscal 1987 budget request for NSF. We commend the Administration for proposing to increase funding for the Biological, Behavioral and Social Sciences (BBS) Directorate by 12.4 percent over projected Fiscal Year 1986 funding levels.

Increases of this magnitude are needed to restore vigor to behavioral and social science research programs at NSF; these programs are still lagging far behind historical levels of support. It is significant that support of behavioral and social science research has fallen from 6.1 percent of NSF's research budget in Fiscal Year 1980, to 4.1 percent in Fiscal Year 1985, and to 4.0 percent proposed for Fiscal Year 1987. Between Fiscal Years 1980 and 1987, in fact, NSF support for the behavioral and social sciences has actually decreased when measured in constant dollars. According to an NSF analysis, projected support for these sciences in Fiscal Year 1986, when adjusted for inflation, is more than 30 percent below the Fiscal Year 1980 levels. During that period, the adjusted budgets for the behavioral and social sciences fell from $62 million to $43 million.

SCIENCE AND ENGINEERING EDUCATION

APA urges the Subcommittee to reiterate its support for the strengthening of science education activities at NSF. We share concerns expressed by Congress many times that improvement is needed in our nation's science education activities. For Fiscal Year 1987 the Administration has proposed that $89 million be authorized for the Science and Engineering Education (SEE) directorate at NSF. We are hopeful that this increase of $2 million or 2.3 percent over Fiscal Year 1986 levels of support is indicative of the Foundation's intentions to adequately fund science education activities. Further, NSF has repeatedly assured Congress that none of the funds appropriated to the program in either Fiscal Years 1986 or 1987 will be deferred into future fiscal years, as was the case between 1983 and 1985. The long-term gains of basic scientific research clearly will not be realized if the scientists and engineers of tomorrow are not adequately prepared today.

We believe that the painstaking rebuilding process undergone by SEE within the Foundation is now paying off. We urge to Subcommittee to consider the possibility of providing additional support for this vital activity at NSF.

ETHICAL RESEARCH ON SCIENCE AND TECHNOLOGY

APA would like to take this opportunity to commend the the Chairman and Members of this Committee, and NSF Director Erich Bloch for actions taken to preserve long-term support of research on the ethical questions often raised by scientific advances. APA encourages NSF to continue its new mode of distributed funding for ethics and values research, and suggests that funding for these activities be raised from $500,000 in Fiscal Year 1986 to $1 million in Fiscal Year 1987 (the activity's level of support before the FY 86 budget cut). APA is particularly pleased that the Foundation is providing for the review of all projects in this area by an ethics advisory committee. It is essential for NSF to ensure that these studies will be properly coordinated and of high quality. As new mechanisms are being created to support these studies, APA encourages Congress to continue overseeing NSF support of research on scientific ethics and values.

BASIC RESEARCH AS AN INVESTMENT

The Administration has proposed significant increases for NSF-supported research -- even in the face of large federal deficits -- with the conviction that investing in basic scientific research will improve our competitiveness internationally and strengthen our scientific base at home. At least eight major studies released in the last three years recommend strong support for basic research. Groups recommending increased Federal support for basic research (which is less likely to attract support from the private sector than applied studies) include the Heritage Foundation, the National Association of Manufacturers, the AFL-CIO, the Business Roundtable, and Georgetown University's Center for Strategic and International Studies.

The behavioral and social sciences have a critical role to play in these efforts to revitalize the nation's economic and technological base. While our international competitors have been quick to recognize these contributions, increases in productivity that could be realized by modifying organizational structures and personnel policies have too often been passed over here in the United States. Indeed, the American Association for the Advancement of Science (AAAS), in Congressional testimony presented earlier this year, emphasized that in areas such as industrial productivity and innovation, "research findings from the behavioral and social sciences frequently are of greater consequence than those from the physical sciences and engineering."

While technological advances must figure prominently in revitalizing this nation's industrial base, human, social and institutional factors can play an even more important role. This is true whether one is addressing the conduct and management of research, the dissemination and marketing of new technical products, or the implementation of new manufacturing processes. A few examples follow:

1) Employee turnover is a costly problem in both the public and private sectors. Even when effects on the productivity of the organization have been disregarded, behavioral scientists estimate that it will cost between $400 and $4,700 (depending on the nature of the position and the organization) to replace each departing employee. A major study of 20 different experiments designed to reduce employee turnover (McEvoy and Cascio, Journal of Applied Psychology, 1985, Vol. 70, No. 2, 342-353) found that programs aimed at "enriching" jobs on average reduced employee turnover by 17 percent. Thus for every 100 employees that an organization has in a particular job category, enriching or redesigning job tasks could save an average company between $6,800 and $79,900 per year.

2) A global study on the impact of organized programs designed to increase employee productivity in the workplace found that the average worker's productivity did, in fact, increase significantly (Guzzo, Jette and Katzell, Personnel Psychology, 1985, Sum. Vol., 38(2), 275-291). This study analyzed the findings of 100 separate studies covering 11 types of psychologically-based organizational interventions. Not all interventions

were equally effective. The most powerful strategies, it was found, were in the areas of employee training and goal setting. Suprisingly, supplying employees with increased financial incentives did not reliably lead to increased productivity. The effects of worker incentive programs varied widely the study found, sounding a warning to those who depend solely on increasing compensation to boost productivity.

3) Research conducted in the United States following the second world war demonstrated techniques to increase the quality of mass produced units through increasing employee decisionmaking (Coch and French, 1948, American Psychologist, 1982, Vol. 37, No. 7, 737-746). This social technology led to the training of production workers in rudimentary research design and statistical techniques enabling them to monitor and become more involved in the production process. This concept, which was originated in the United States, evolved into the unique Japanese technology, "quality control circles." The high overall quality of the Japanese automobile industry is attributable in part to the effects of quality control circles.

While there is a great need to conduct more research on the development of strategies and conditions critical to more efficiently utilizing the nation's human resources, such studies, for the most part, are not supported at the National Science Foundation. Primarily, NSF funding for the behavioral and social sciences has gone to support individual investigators pursuing the fundamental questions on human behavior and mental functioning. This is the type of work which forms the base for studies on improving productivity such as those already cited in this testimony. For example, social psychology research projects at NSF last year included basic studies on group opinion changes, social perception and the processing of social information. Findings emerging from these studies may be used to guide other behavioral scientists in devising strategies to be used in motivating employees. Similarly, basic research in the cognitive sciences last year included fundamental studies on knowledge acquisition, decision-making, and memory. Clearly advances in these areas are key to developing new, more effective educational and training strategies.

It is in the support of such basic, fundamental research in which NSF has the greatest role to play. Simply put, without the provision of additional financial inducements, support for these studies is rarely available from the private-sector since the ultimate payoff for these basic studies is often not readily apparent. Currently, behavioral and social science research is specifically excluded from the law which grants tax credits to industry in return for their support of basic scientific research.

Thank you again for the opportunity to present this statement. It has focused on the contributions that the behavioral and social sciences make to increasing the nation's productivity and international competitiveness. Of course, psychologists engage in many other areas of research. Their activities form an impressive array of inquiry which ranges from purely physiological phenomena to purely social phenomena and includes such diverse topics as normal and abnoramal brain growth and development; educational processes such as learning and memory; the study of social institutions and interactions; survey research; and the development of standardized tests with many applications in both the public and private sectors.

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Mechanical Engineers

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March 5, 1986

Honorable Doug Walgren
Chairman
Subcommittee on Science, Research
& Technology
House Committee on Science & Technology
2319 Rayburn House Office Building
Washington, D.C. 20515

Dear Mr. Chairman:

The American Society of Mechanical Engineers (ASME) is concerned about the programs and mission of the National Science Foundation (NSF). Recently a task force of ASME's Board on Engineering Education, of which I am chairman, prepared a statement on the Fiscal Year 1987 NSF Budget Authorization. Since your Subcommittee recently held hearings on the NSF budget request, I thought you might find the comments useful and I would ask that our comments be included in the permanent record of those hearings.

If you have any questions or comments concerning our statement, please feel free to contact Lee White of the ASME Washington office at 785-3756.

Sincerely,

Winfred M. Phillips

Dr. Winfred M. Phillips
Chairman
Task Force on the
National Science Foundation FY 1987 Budget

cc: J. B. Jones

LJW/WMP:lh
1083A
Enclosure

Comments on

The National Science Foundation
FY 1987
Budget Request

Submitted to

Subcommittee on Science, Research and Technology
Committee on Science and Technology
U.S. House of Representatives

Prepared by

A Task Force of
the Board on Engineering Education
The American Society of
Mechanical Engineers

February 18, 1986

Mr. Chairman and Members of the Committee:

We appreciate the opportunity to submit our views on the proposed fiscal year 1987 budget of the National Science Foundation. The American Society of Mechanical Engineers (ASME) is an educational, scientific and charitable society founded over one hundred years ago. Membership in ASME exceeds 110,000 professionals in mechanical engineering. This statement was prepared by a Task Force of the Board on Education of the American Society of Mechanical Engineers. It represents the considered judgement of the Task Force, a group of experts in the field, rather than an official position of ASME.

ASME continues its vital interest in the successful implementation of the full range of NSF programs. These comments, however, focus primarily on those aspects of the budget request affecting the contributions of engineering research to national goals.

The Task Force endorses the testimony of NSF Director Erich Bloch before this Subcommittee on February 20 regarding the need for a sustained high level of Federal support for basic science and engineering research. This support is required to insure continued U.S. pre-eminence in the world marketplace and for national security. We are especially pleased with the Foundation's long-term commitment to ensure stability of basic research programs. We are also pleased with the continued efforts to restore support for science and engineering education which was drastically curtailed in the 1982-83 period. However, we strongly urge further strengthening of NSF basic research programs in engineering.

OVERVIEW: NSF ENGINEERING BUDGET

The FY 1987 budget request for the NSF Engineering Directorate is $185.5 million. This is an increase of $23 million or 14.2% over the current FY 1986 plan of $162.5 million; it would be a $30 million or 19.3% increase over the FY 1986 plan of $155.5 million after the Gramm-Rudman-Hollings reduction. These proposed increases are admirable in the face of the efforts to reduce the deficit and balance the budget by 1991. They demonstrate the Administration's commitment to basic engineering research.

However, it is important to examine the realities of the budgetary processs by considering the FY 1986 NSF Engineering Budget Request and its outcome as illustrated below.

NSF Engineering Budget
(Millions of Dollars)

Actual	Budget Request	Current Plan	Net After GRH Reduction
FY 1985	FY 1986	FY 1986	FY 1986
150.6M	170.1M	162.5M	155.5M

The current plan calls for a 7.9% increase over FY 1985, and if Gramm-Rudman-Hollings or an equivalent is enacted, there would be only a 3.4% increase over FY 1985. The impact of both of these reduced increases must be emphasized.

The FY 1986 budget contains an increase over FY 1985 of $13M for Engineering Research Centers. It is clear that at best this increase constitutes the total increase in the Engineering Budget for FY 1986. The other programs would thus remain at or near their FY 1985 levels. As we pointed out to this Subcommittee last year, for many of these programs, particularly those in the basic engineering areas, the FY 1985 spending levels were at or below their FY 1984 levels. If this trend continues, it could result in a 50% reduction over 1984 levels in the number of investigators and engineering graduate students supported in 1990.

This is an issue of great concern, because the engineering faculty shortage continues. NSF research is an important part of engineering faculty activity, and graduate students are the source of tomorrow's faculty; those who generate the engineering manpower of tomorrow for the nation.

The recent reorganization of the Engineering Directorate has been accomplished by coalescing synergistic and like programs together on a generic needs basis, rather than on a traditional academic department basis. The intent of reorganization has been to place more focus on fundamental research that can ultimately impact on the highest priority research needs.

Well founded concerns have been raised by some members of the research community (and members of the MEAM Division Advisory Committee) about the apparent de-emphasis of some of the traditional engineering science programs (e.g., fluid mechanics and solid mechanics) and the "submergence" of others (e.g., heat transfer - at least in name). Few can question the importance of continuing to strengthen the science base in these traditional engineering science areas. Likewise, few can ignore the dilemma that the U.S. faces in maintaining international competitiveness in manufactured goods and in the underlying technological base.

Clearly, we have too long neglected the design and manufacturing areas, and we have not established the needed science base for these vital areas. These areas have had only limited emphasis at the NSF until recently. Likewise, the rapidly emerging technology of computer engineering has a very limited science base and this too has received limited emphasis at the NSF. It seems clear that NSF must play a prominent role as a catalyst in developing a new and fundamental knowledge base in the emerging areas of design, manufacturing and computer technology, and that the cost of doing so will be enormous.

One result of the reorganization may be a new awareness on the part of university researchers that new organizational structures may be required to address fundamental research issues that relate to national priorities. Several aspects of the reorganization deal with developing significant ties between universities and industry. Until recently, industry has been slow to acknowledge its role in supporting university research and facilities development.

Three programs, including two new ones, relate to the NSF's role in stimulating and strengthening industry-university ties--the Engineering Research Centers Program, the University Research Centers Program, and the Presidential Young Investigator's Program. These three programs are mutually supportive and address different priority needs. The ERCs are directed toward needs for major advances in emerging and critical technologies. Considerable leveraging of NSF funds with industry funds should occur as these centers mature.

It was wise for NSF to retain the Industry-University Research Centers Program (see Appendix I), at least while the ERC Program is being developed, and to move this program to the Engineering Directorate from the Scientific, Technological and International Affairs Directorate. Centers initiated under this program must provide large leveraging of NSF funds and demonstrate high potential for continuing support from industry after the NSF "seed" has stopped. The NSF has had success with this program. In FY 85, an NSF investment of $3 million in 30 centers resulted in a $25 million investment by state governments and industry.

The Presidential Young Investigators Program has already had a profound influence on the morale and productivity of outstanding young investigators. The PYI Program is structured to ensure that the recipients will have the opportunity to do fundamental research that requires continuity of funding over a five or more year period, and still maintain perspective on the long term benefit of that research to the nation. Moreover, the recipient must establish real and meaningful ties with industry if maximum funding is desired.

The proposed FY 1987 budget for the Engineering Directorate appears to be inconsistent with the need to continue implementation of the reorganization plan, and to continue those new initiatives that address national priorities.

There simply is too little money provided to the Engineering Directorate to fund individual investigators, PYI's, ERC's, etc., and still introduce new programs in design, manufacturing, computer engineering, and critical technologies. Congress must understand that fundamental engineering research is as vital to the economic vitality and defense of the nation, as basic research in the sciences. We have included in our Appendix II a discussion of fundamental engineering research.

An equally critical issue is the impact of this continuing imbalance on engineering manpower development for engineering education and practice. A particular crisis exists in mechanical engineering education -- especially in the emerging areas of mechanical engineering.

An even more significant problem is the present discrepancy between the education of many of the nation's mechanical engineers and the skills and knowledge they need to be effective in the industrial and defense sectors in the future. University Mechanical Engineering Departments do an excellent job in teaching engineering science, analysis, and many aspects of the experimental and design processes that are important elements of engineering practice. But, most institutions fall short in terms of providing education in some of the critical and emerging technologies related to computer-integrated design and manufacturing, and the engineering science base related to these technologies. The shortfall begins with the shortage of fundamental research support in the emerging mechanical engineering disciplines which would permit faculty development, support of graduate education, and development of a knowledge base essential for curriculum development and practice.

We now move to comments on the specific engineering divisions at NSF.

THE ENGINEERING SCIENCE DIVISION FOR CHEMICAL, BIOCHEMICAL, AND THERMAL ENGINEERING

One of the underlying objectives of the NSF in FY 1987 is "to strengthen multidisciplinary research and training in engineering at universities." In the formation of this Division as part of the reorganization, new and improved symbiotic relationships were created between programs related to chemical, biochemical, and thermal processes. This is particularly true in the Division's Thermal Systems and Engineering Program, which is a merger of previous programs in heat transfer, thermal systems, and combustion.

Of the five programs in this Division, the Thermal Systems and Engineering Program is the largest and most central to mechanical engineering education and practice. Approximately 35% of the 3800 mechanical engineering faculty members in U.S. universities teach and do research in the thermal systems area. Fundamental research in thermal systems impacts on virtually every industry and product - e.g., manufacturing, transportation, health care and human rehabilitation, defense systems, and the supply of energy, materials and food. The U.S. is rapidly losing still another basic industry - i.e., aluminum production - because insufficient understanding exists on how to solve the thermal systems problems - i.e., how to reduce the amount of energy required to produce aluminum so that the total production cost is produce the aluminum so that the total production cost is competitive with that of competitors in other countries.

Increased understanding of the behavior and operating limits of industrial thermal processes, equipment, and components relates significantly to long term restoration of the competitive position of U.S. industry in world markets. Clearly, the requested $9 million for this program in FY 1987 is very modest considering the pervasiveness of thermal processes. It is also important to note that progress in this field would contribute to a reduction in energy consumption, which remains a national priority.

ENGINEERING SCIENCE IN MECHANICS, STRUCTURE, AND MATERIALS ENGINEERING
The purpose of this division is to expand the engineering science base in the behavior of solids and fluids under dynamic loading. The budget situation for this division is:

Program Element	Actual FY 1985	Current Plan FY 1986	Net After GRH Red. FY 1986	Requested FY 1987
Solid and Geomechanics	6.0	6.1	5.8	6.5
Structures and Building Systems	4.3	3.9	3.7	3.6
Fluid Dynamics and Hydraulics	5.3	5.6	5.4	6.1
Tribology	1.9	2.0	1.9	2.2
Dynamic Systems and Control	2.8	2.8	2.7	2.9
Materials Engineering and Processing	3.1	3.3	3.2	5.0
Total	23.3	23.7	22.7	26.3

We are pleased to see the proposed increase in materials engineering, which is a high priority for ASME. However, the total budget for this division for FY 1985 and FY 1986 will be approximately the same. Given that the best FY 1986 budget is only 4% above the Actual FY 1984 expenditures, the activities of this division have been severely curtailed in the past few years. The proposed 10.8% increase is essential to maintain this division activities at an acceptable level. Given the prospects for further budget cuts and given that each program has to support a specified number of Presidential Young Investigator Awards, the funds available for the support of research in most of the programs in this division have been decreasing. Considering the increase in costs of supporting research it is possible that, if these funding trends continue, the number of investigators and graduate students supported by these programs could be half of their 1984 levels by 1989.

It is therefore essential that this basic engineering division be given a high priority for budgetary increases. If the budgetary trends in this division are not reversed, we are concerned about the long-term implications on high-risk research. Such high-risk research may lead to breakthroughs that have major impacts on U.S. competitiveness.

ENGINEERING SCIENCE IN ELECTRICAL, COMMUNICATIONS AND SYSTEMS ENGINEERING

This basic engineering division supports research on the analysis, design and fabrication of devices and systems. The budget situation of this division is:

Program Element	Actual FY 1985	Current Plan FY 1986	Net After GRH Red FY 1986	Request FY 1987
Solid State and Microstructures	7.7	7.2	6.9	7.3
Communications Systems Signal Processing	5.1	5.3	5.1	5.5
Systems Theory and Operations Research	5.1	5.2	5.0	5.4
Quantum Electronics Waves and Beams	4.9	4.9	4.7	5.0
Instrumentation, Sensing and Measurement	3.0	3.1	2.9	3.1
Total	25.8	25.7	24.6	26.3

This basic engineering division's funding levels are maintained nearly level from FY 1985 to FY 1987 with a small increase of 2.2% requested. It is unfortunate that the program on novel research in instrumentation and measurement did not receive the planned 34% increase in FY 1986. This field of research was one of the key objectives of the restructuring of the Engineering Directorate in FY 1985. We believe that the advancement of instrumentation, sensors and measurement technology is of vital importance to maintaining and improving the competitiveness of U.S. industry. This is an important need in a much neglected area of advanced technology.

This division (as other basic engineering divisions) needs increases to maintain a minimum quality in each program. We would thus recommend an increase of $2.07 million or 8.1% over the current plan FY 1986. We believe that this increase should be a priority for the Engineering Directorate.

THE DIVISION OF DESIGN, MANUFACTURING AND COMPUTER ENGINEERING

We are pleased to see the increased support for manufacturing and related research, which is a major area of emphasis in the ASME technical programs. Unlike the traditional, "mature" mechanical engineering related disciplines of thermodynamics, fluid mechanics, heat transfer, and solid mechanics, the disciplines encompassed by design, manufacturing and computer engineering are only now emerging and being codified. They lack a strong science base, but such a base appears feasible. These "emerging disciplines" provide an integrating framework for the continued significance of the mature mechanical engineering disciplines. Moreover, these emerging disciplines are of vital importance to the international competitive strength of the U.S. The new organization of the NSF Engineering Directorate highlights and emphasizes the critical and central importance of these emerging disciplines, as well as the importance of their integrating nature. Moreover, the mission statement of the new division reflects the strong coupling that exists between these three separate areas.

These emerging disciplines have been neglected within the universities so long that major new initiatives are needed to revitalize the related instruction and research programs, and to rebuild the human resource base needed. It is interesting that some university faculty members who formerly worked in the traditional engineering science areas are now migrating to these emerging disciplines. This shift is fortunate, since there will follow a better understanding of the need to focus on fundamental research issues.

There appears to be a clear dichotomy between the fundamental and generic research needs that should and will be addressed through the Division's programs, and those that should be addressed by industry and other federal agencies.

In a study of "Research Needs in Mechanical Systems" conducted for the NSF by the ASME, four basic disciplines were identified as being of critical importance to the economic health of the nation: dynamic systems and control, design methodology and interactive computer graphics, machine dynamics, and tribology. In addition, a principal outcome of the study was the recognition that developing national capability in computer-integrated systems and design and implementation is the single most important issue in the field of mechanical systems. On this last point, it was concluded that a major national initiative is needed in computer integration: in design, manufacturing and operations; in intelligent products; in the computer-human interface; and in the processes of education and professional practice. It was recognized that this need goes far beyond the field of mechanical systems and is, in fact, a major national need in all engineering fields. The programs in the new division are structured to address this national need.

The ASME study of Research Needs in Mechanical Systems, and several other NSF supported studies, have had a profound influence on the new structure and mission of the Engineering Directorate. The major recommendations of the ASME study have been fully incorporated. The NSF has been responsive to input from the research community and quite perceptive of their role in focusing on national priorities. We have recently proposed a similar study of reseach needs in manufacturing to assist NSF and DOD in identifying research imperatives with the greatest potential for advancing U.S. technological leadership.

The emergence of the fields of artificial intelligence and expert systems promises to provide the stimulus for greater understanding of design as a process, as well as guide the development of fundamental axioms for design. The continued development of the tools of geometric modeling, and more generally interactive computer graphics, can potentially revolutionize the way design is done, and the way in which design results are transferred into quality and competitive manufactured products.

The programs in the new division support research aimed at developing the base of scientific knowledge needed for rapid advances in design and manufacturing. Without such advances, the international competitiveness of U.S. industry will continue to erode, and more basic industries will move offshore.

EMERGING AND CRITICAL ENGINEERING SYSTEMS

The proposed NSF Budget incorporates an 18.8% increase in 1987 funding compared to the current plan for FY 1986. Particularly impressive are the large increases in Biotechnology ($2,000,000) and Computational Engineering ($3,000,000). Both represent a continuation of emphasis from 1986, even though the computational engineering activities in FY 1986 were carried out as part of different programs. Biotechnology represents in many ways a new frontier and an opportunity for the United States to maintain a position of leadership in an area that may affect very profoundly our future technological strength. Computational engineering is an area where foreign competition is becoming stronger; the importance of this field is paramount not only from the point of view of overall technological leadership, but also from the points of view of productivity and of national defense.

Some researchers may regret that the more focused approach of the NSF Engineering budget in the last two years may have limited somewhat their traditional freedom. However, in view of the increasing technological challenges facing the United States, it is proper for the NSF to take a position of leadership in shaping the research directions for the future. As we stated last year, the courage of NSF in accepting this role "is needed and is to be applauded."

Most of the other activities in the Emerging and Critical Systems areas would also be strengthened by the proposed FY 1987 budget, although more modestly than Biotechnology and Computational Engineering.

CROSS DISCIPLINARY RESEARCH

This activity has gained tremendously in importance with the initiation of the NSF Engineering Research Center (ERC) program. The key role that such Centers can play in fostering cross-disciplinary research was clearly defined in the report from the National Academy of Engineering that originally proposed this new approach. Since the inception of this program, 244 ERC proposals have been received from 178 academic institutions, showing the strong academic interest in these activities. Possibly even more significant is the fact that 91 industrial firms are participating with the first six centers established under the program in FY 1985. This strong industrial support indicates the widely held belief that these centers will contribute significantly to American industrial productivity and international competitiveness.

ASME is firmly committed to encouraging cross-disciplinary research that provides for the involvement of industry, universities and government. Our new Institute for Innovative Excavation Equipment and Systems, for example, will involve personnel from electrical, civil, mining, computer ~~engineering~~, mechanical, industrial and other engineering departments from universities all across the country. Researchers from these departments will work together with personnel from industrial and government laboratories on projects of mutual interest.

The proposed 1987 increase in the Engineering Research Center program is $12,000,000. This increase is offset in part by the termination of the Industry/University Projects activity, a $3,000,000 saving. The rationale given for the termination of this activity is that projects of this type "will continue to be supported through the disciplinary research programs Foundation-wide."

The remaining activity under the Cross-Disciplinary heading, the Industry/University Research Centers, is projected to continue at the same level as in FY 1986.

CONCLUSIONS AND RECOMMENDATIONS

The proposed FY 1987 budget request for engineering programs is admirable considering the existing budget climate. However, we are very concerned about trends in support for fundmental engineering research.

Although we strongly support the Engineering Research Center program, it should not come at the expense of basic engineering research. Therefore, we make the following recommendations:

1. In FY 1987, NSF should continue to support the eleven ERC's initiated in FY 1985 and FY 1986 at a funding level of $26 million. This would be an increase of $4 million and give each ERC an average of $2.4 million. We believe this is a strong level of support for existing centers, and recognize that it does not allow for any new centers in FY 1987. However, it should be noted that other agencies such as the Navy, Army, Air Force and DARPA are planning to support ERCs in FY 1986 and FY 1987.

2. The new initiative in Computational Engineering should be postponed to a later date. Although we support the need for new initiatives in the computer

area, NSF has a major commitment to this in other special programs; and to start a new program in a tight budget year is questionable.

3. The monies saved from taking the above steps should be reallocated to programs in the basic engineering divisions where it can have the most effect such as Chemical, Biochemical and Thermal Engineering; Mechanics, Structures and Materials Engineering; and Electrical, Communications and Systems engineering.

Finally, in keeping with the new more active role of NSF in defining national needs for engineering research, the ASME is ready and willing to assist in providing advice and counsel for the definition of long-range issues which may impact U.S. competitiveness in a wide range of engineering specialties. This is a role for which the ASME is well-equipped, since we are already structured to address cross-discipline engineering interests within major industrial divisions. We have been active for many years in stimulating cross-disciplinary dialogues among our members in recognition of the fact that modern technology embraces many facets of the more traditional disciplines in science-based engineering specialties.

NSF efforts and endorsements of engineering research are admirable and the staff of the Foundation are to be soundly applauded for their foresight in emphasizing engineering research and education. We trust that the Congress will endorse these efforts and further encourage the strengthening of basic engineering research which is the foundation of our technological future.

Appendix I

(Information Item)

National Science Foundation

University/Industry Cooperative Research Centers

The University/Industry Cooperative Research Centers Program initiated by the National Science Foundation in 1973, stimulates industrial support of university research. This is accomplished through the establishment of centers that create long term collaboration between the university and industry in research areas of high mutual interest. The program initiates university research programs, with cofunding from groups of industrial firms that are compatible with university research objectives and also responsive to industry's research needs.

NSF and industry's joint support in initiating a center provide for a broad-based research program that is of interest to industry. Research programs of the centers generally correspond to the university's scientific and engineering areas of expertise and generally have participants that are or have been principal investigators of other NSF research grants. Most centers have or develop an interdisciplinary research program to meet industry's research needs. All centers are expected to increase the industrial support covering both direct funding and equipment for their research program as NSF support is phased out within a period of five years. A center is considered a success when its research funding is at its original level or higher and NSF no longer provides support. Most centers level off at the $500,000 - $1,000,000 annual level in non-Federal support.

The program usually starts out with a planning grant to study possible alternatives for both structure and content of the research and management plan to be pursued, and to evaluate industry's interest in supporting a potential center. Successful planning can be followed by an operations grant leading to self-sufficiency within 5 years. Since the program emphasizes local autonomy and separate development, each center develops along its independent path determined by the principal investigator, the university policy and objectives, and the industry requirement. NSF views each center as an experiment and funds an independent evaluation to study the variables of each center's operation to assess its outcome and improve upon future center development.

At the present time there are over 30 centers in either the operations phase (majority of funding from non-Federal sources) or planning phase (primary funding from NSF to develop research agenda, structure and non-Federal support). During 1985, total funding from industry, state government and NSF was in excess of $25M per year. NSF's current investment of $3M has thus been leveraged by non-Federal funds by about 8 to 1. Industrial support for the centers has not only grown in dollars but the number of companies committing funds increased to over 200 in 1985.

A listing of all Centers is attached.

IUCR Centers (As of Oct 1, 1985)

Location	Research Area	Initiated	P.I. Name
Massachusetts Inst. of Technology	Polymers (Processing)	1973	Dr. T. Gutowski
Rensselaer Polytechnic Inst.	Computer Graphics	1979	Dr. M. Wozney
University of Massachusetts	Polymers (Properties)	1980	Dr. S.W. Kantor
Ohio State University	Welding	1980	Dr. K. Graff
Case-Western Reserve University	Polymers (Applied)	1981	Dr. Anne P. Hiltner
University of Rhode Island	Robotics	1982	Dr. H. Viets
North Carolina State University	Telecommunications	1982	Dr. S. Chitsaz
Rutgers University	Ceramics	1982	Dr. J. Wachtman
Georgia Institute of Technology	Materials Handling	1983	Dr. J. White
Worcester Polytechnic Inst.	Automation Technology	1983	Dr. A. Gerstenfeld
Texas A&M University	Hydrogen Technology	1983	Dr. J. Bockris
Pennsylvania State University	Dielectrics	1983	Dr. J. Biggers
Colorado School of Mines	Steel Processing	1984	Dr. G. Krauss
University of Washington	Process Analytical Chemistry	1984	Dr. B. Kowalski

Appendix II

(Information Item)

Fundamental Engineering Research

The similarities between science and engineering research are many. The scientific approach is applicable to both science research and engineering research. The terms basic and applied research, which represent research throughout the National Science Foundation, are difficult to define. The same work done by a scientist and engineer may be classified as basic by the former and applied by the latter. Pure research is often used by some as a further subdivision of basic research.

Fundamental engineering research is vital to the national welfare and security. Without a definite focus on a specified application, most industries only sparingly support long-range fundamental engineering research. The results of fundamental research are a part of the national wealth upon which all can draw for future use. Thus, the government is the logical source of support, and NSF is the responsible agency within government. Further, some research subjects of interest and value do not have an industry counterpart until the fundamental engineering research is accomplished.

Fundamental engineering research focuses on man-made systems, or artifacts, while basic science research is more often directed to natural systems. Fundamental engineering research includes basic and applied activities. There is no value judgement regarding basic and applied research, rather research is considered on the basis of competent performance, intrinsic merit and utility or relevance. Fundamental engineering research is that research fundamental

Appendix II

(Information Item)

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App.II (cont.)

to the engineering process.

Fundamental research in engineering includes:

- formulating scientifically-based principles and concepts
- developing the knowledge base that leads to technological development
- advancing the basic knowledge that might be applied to analysis, synthesis, and design of a large variety of man-made systems
- developing and using new scientific knowledge for new or improved systems
- providing advanced instruments for research

The results of fundamental engineering research should apply to more than one applied project and should not be site specific

1/86

Task Force on the National Science Foundation FY 1987 Budget

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Testimony

by

Robert Schleiger
President
Chesapeake College
Wye Mills, Maryland

Subcommittee on Science, Research and Technology
Committee on Science and Technology
U.S. HOUSE OF REPRESENTATIVES
February 26, 1986

Chairman Walgren, members of the sub-committee, my name is Robert Schleiger. I am the President of Chesapeake College, a community college serving the rural counties of Caroline, Dorchester, Kent, Queen Anne's, and Talbot on the Eastern Shore of Maryland. The college has just celebrated its twentieth anniversary of serving the academic and career needs of the citizens and businesses of the Eastern Shore of Maryland. Our mission statement is similar to those of other community colleges in that we primarily are teaching institutions and we do not have an emphasis on research. Approximately 50 percent of all the students in community colleges throughout the country transfer to four-year institutions after receiving their associate degrees. The same percentage of Chesapeake College's students also follow this pattern in transferring to four-year institutions for their junior and senior years. We offer 9 different courses in biology, 4 different courses in chemistry, 2 courses in physics, and 13 different courses in mathematics, for our students to consider in preparation for specialized programs in the four-year institutions. Many of our students are taking their associate degree programs in preparation of entering professional fields in the health related area and advanced science work. These students have performed credibly in the areas of science and mathematics at the four-year institutions after completing their course work and receiving their associate degrees at Chesapeake College.

MANY STUDIES THROUGHOUT THE COUNTRY HAVE SHOWN THAT STUDENTS WHO GRADUATE FROM A COMMUNITY COLLEGE WITH AN ASSOCIATE DEGREE AND MOVE INTO THE JUNIOR YEAR OF A FOUR-YEAR INSTITUTION PERFORM AS WELL IN THE JUNIOR AND SENIOR YEAR AS THOSE STUDENTS WHO STARTED THEIR FRESHMAN YEAR AT THE FOUR-YEAR INSTITUTION. THIS IS QUITE A SIGNIFICANT ACCOMPLISHMENT SINCE THE FOUR-YEAR INSTITUTIONS HAVE A SELECTIVE PROCESS FOR ADMISSIONS FOR FRESHMAN WHILE COMMUNITY COLLEGES HAVE AN OPEN-DOOR ADMISSION POLICY. YOU WILL FIND THAT THE STUDENTS PERFORM NOT ONLY IN GENERAL COURSE WORK IN THIS REGARD BUT ALSO IN THE SCIENCE AND TECHNOLOGIES. THIS IS PARTICULARLY IMPORTANT SINCE, HISTORICALLY, OVER 50 PERCENT OF ALL THE ENTERING FRESHMEN AT POSTSECONDARY INSTITUTIONS THROUGHOUT THE COUNTRY BEGIN BY ATTENDING COMMUNITY COLLEGES. THIS MEANS THAT THIS LARGE SEGMENT OF STUDENTS IS THE MAINSTREAM OF THOSE STUDENTS MOVING THROUGH THE POSTSECONDARY SYSTEM AND, IN THE PAST, HAVE BEEN COMPLETELY OVERLOOKED BY THE NATIONAL SCIENCE FOUNDATION IN ITS AWARDING OF GRANTS AND SUBSIDIES.

IT IS IMPORTANT, THEREFORE, THAT THE NATIONAL SCIENCE FOUNDATION BEGIN LOOKING AT TWO-YEAR COMMUNITY COLLEGES AND ADDRESSING THEIR NEEDS AS WELL AS THE NEEDS OF FOUR-YEAR INSTITUTIONS. THIS IS PARTICULARLY TRUE BECAUSE, AS INDICATED EARLIER, COMMUNITY COLLEGES ARE TEACHING INSTITUTIONS AND THE PRIMARY FUNCTION OF THEIR FACULTY MEMBERS IS TO TEACH AND TO KEEP CURRENT IN THEIR FIELDS OF TEACHING. THIS PRESENTS A PROBLEM OF NOT HAVING ENOUGH TIME AVAILABLE FOR ADDITIONAL STUDY OR STAFF DEVELOPMENT BECAUSE THE HEAVY TEACHING LOADS DO NOT ALLOW FACULTY RELEASE TIME TO PURSUE RESEARCH OR WRITING. COMMUNITY COLLEGE FACULTY MEMBERS

ARE DEDICATED AND COMMITTED TO WORKING WITH STUDENTS TO SEE THAT THEY SUCCEED IN THEIR FIELDS OF ENDEAVOR. MOST OF THE FREE TIME THE COLLEGE FACULTY MEMBERS HAVE IS SPENT IN COUNSELING OR ASSISTING STUDENTS IN THEIR PROGRAMS. THIS PRIMARY THRUST IS UNIQUE TO COMMUNITY COLLEGE FACULTY.

IN ADDITION TO THE VERY SUCCESSFUL ACADEMIC PROGRAMS AT THE COMMUNITY COLLEGES WHICH PREPARE STUDENTS TO TRANSFER TO FOUR-YEAR INSTITUTIONS FOR ADDITIONAL STUDY, THERE IS THE OTHER HALF OF THE COMMUNITY COLLEGE STUDENT BODY; THOSE STUDENTS IN CAREER PROGRAMS LEADING TO IMMEDIATE EMPLOYMENT UPON COMPLETION OF THEIR PROGRAMS. THIS PORTION OF THE STUDENT BODY HAS A TREMENDOUS IMPACT ON THE SKILL LEVEL OF CURRENT JOB PERFORMANCE AND THE FUTURE SKILL PERFORMANCE IN MANY OF OUR TECHNICAL FIELDS. THIS SKILL BASE OF OUR WORK FORCE IS VITAL TO THE OVERALL ECONOMIC DEVELOPMENT OF OUR BUSINESSES AND INDUSTRY IN THE UNITED STATES AS WELL AS ALL OF THE SEGMENTS OF OUR MILITARY ESTABLISHMENTS. THE MAJOR FOCUS FOR THE DEVELOPMENT OF THIS SKILL BASE IS THROUGH THE COMMUNITY COLLEGE SYSTEM THROUGHOUT THE COUNTRY, AND A GREAT DEAL OF EMPHASIS IN THIS SKILL LEVEL IS IN THE SCIENCE AND MATHEMATICS AREAS. OUR FACULTY MEMBERS WORK VERY CLOSELY WITH PROGRAM ADVISORY COMMITTEES ON THE LEVEL OF SKILLS AND THE IMPROVEMENT OF SKILLS THAT ARE NECESSARY TO PROVIDE BUSINESS AND INDUSTRY AND MILITARY ESTABLISHMENTS THROUGHOUT THE COUNTRY WITH STUDENTS WHO WILL PERFORM AT A HIGH LEVEL IN THE VARIOUS TECHNOLOGIES. THE FACULTY MEMBERS IN THE TECHNOLOGIES ALSO HAVE INSTRUCTION AS THEIR PRIMARY FUNCTION. THEY WORK CLOSELY WITH STUDENTS TO SEE THAT THEY HAVE DEVELOPED THE COMPETENCIES, UPON THE COMPLETION OF THEIR PROGRAMS, TO HAVE A

HIGH LEVEL OF PERFORMANCE AS REQUIRED IN THEIR CHOSEN FIELDS. THESE FACULTY MEMBERS ALSO DO NOT HAVE RELEASE TIME FOR RESEARCH OR WRITING YET MUST SPEND THEIR TIME KEEPING CURRENT WITH THE LATEST TECHNOLOGIES IN THEIR PARTICULAR PROGRAMS. AGAIN, THERE IS A HEAVY EMPHASIS IN THE AREAS OF SCIENCE AND THE TECHNOLOGIES. THE NATIONAL SCIENCE FOUNDATION NEEDS TO GIVE CONSIDERATION TO THIS CRITICAL NEED OF FACULTY MEMBERS AT COMMUNITY COLLEGES AND DEVELOP SOME TYPE OF ASSISTANCE PROGRAM THAT WILL PROVIDE THESE FACULTY MEMBERS WITH THE OPPORTUNITY FOR ADDITIONAL STUDY OR WORK IN AN EFFORT TO INCREASE THEIR COMPETENCIES IN THE NEW TECHNOLOGIES ON A REGULAR BASIS.

THE POSTSECONDARY EDUCATIONAL SYSTEM THROUGHOUT THE UNITED STATES IS VITAL TO THE CONTINUED SUCCESS OF THE FOUNDATION OF BUSINESS AND TECHNOLOGY. HOWEVER, THE EMPHASIS BY THE NATIONAL SCIENCE FOUNDATION IN THE PAST HAS BEEN TO GIVE ASSISTANCE TO THE FOUR-YEAR INSTITUTIONS FOR THEIR FACULTY. THERE IS AN URGENT NEED FOR THE NATIONAL SCIENCE FOUNDATION TO GIVE EQUAL CONSIDERATION TO THE MISSION OF THE COMMUNITY COLLEGES AND THE NEEDS OF THEIR FACULTY MEMBERS THAT COMPRISE THIS LARGE SEGMENT OF EDUCATIONAL RESOURCES THROUGHOUT THE COUNTRY.

EACH CONGRESSIONAL DISTRICT IN THE COUNTRY HAS AT LEAST ONE COMMUNITY COLLEGE WITHIN ITS BOUNDARIES. THESE COMMUNITY COLLEGES WERE DESIGNED TO MEET THE NEEDS OF THEIR CONSTITUENCIES. WE FEEL THAT COMMUNITY COLLEGES HAVE DONE AN EXCELLENT JOB IN THIS ENDEAVOR. HOWEVER, THERE IS A LIMIT TO THE RESOURCES AVAILABLE TO THE COMMUNITY COLLEGES TO KEEP THEIR FACULTY CURRENT AND ABREAST OF THE NEEDS OF ALL ACADEMIC AND TECHNICAL AREAS, ESPECIALLY IN THE CRITICAL AREAS OF SCIENCE AND MATHEMATICS. ASSISTANCE FROM THE NATIONAL SCIENCE FOUNDATION AS WELL AS OTHER FOUNDATIONS COULD GREATLY BENEFIT THE COUNTRY AS A WHOLE AND PARTICULARLY INDIVIDUAL SERVICE AREAS BY ASSISTING TO PROVIDE THE COMMUNITY COLLEGES THE ADDITIONAL RESOURCES WITH WHICH TO IMPROVE THE TEACHING OF THE SCIENCES AND MATHEMATICS.

THANK YOU FOR THE OPPORTUNITY TO PRESENT THESE COMMENTS TO YOU.

Testimony by Pauline H. Brooks
Director of Public Television Development
Children's Television Workshop

To the House Committee on Science and Technology

Subject: Authorization for National Science Foundation/
Science and Engineering Education Directorate

March 1, 1986

Mr. Chairman and members of the Committee:

The Children's Television Workshop urges this Committee and the Congress to authorize an adequate level of funds to enable the National Science Foundation to continue its vital support of science education.

The Children's Television Workshop has a direct interest in these matters. The National Science Foundation's Science and Engineering Education Directorate (NSF-SEE) provides partial funding, at the level of $1.5 million plus per year, for 3-2-1 CONTACT, our educational television series that aims to make science more appealing and understandable to its millions of 8-to-12 year-old viewers.

NSF-SEE has also committed $5 million for the first season of a new Children's Television Workshop series on mathematics for 8-to-12 year-olds. Other support will be provided by the U.S. Department of Education, The Corporation for Public Broadcasting, foundations and the IBM Corporation.

This new mathematics series will help address the national crisis in math education by using the power and impact of television:

- to promote enthusiasm for and interest in mathematics;
- to encourage the use and application of problem-solving strategies in mathematics;
- and to present sound mathematical content in an interesting, assessible and meaningful manner.

The 75 half-hour programs will be suitable for viewing both at home and in the classroom, and teachers guides will be available. The anticipated airdate is January 1987.

As with 3-2-1 CONTACT, we anticipate that the series will be fed to public television stations both during the day for school use and in the late afternoon for home viewing.

The National Science Foundation has recognized the power of broadcast television as a constructive and cost-effective educational tool. In the case of 3-2-1 CONTACT and our proposed math series, it is a tool which can be used both in school settings and with a large at-home audience of children, and often their parents as well. And their commitment is leveraging financial support from other agencies, both private and Federal, to help attack the crisis in math education in this country.

America's industrial leadership rests on science and technology, but it is increasingly clear that these fields are not very appealing to America's young people. The national problem with scientific literacy, as well as the tiny proportion of students electing to pursue higher education in science, does not occur merely at the high school level. The problem starts at the elementary grades, where teachers are least prepared to teach science, and where states are least rigorous in setting standards for science curriculum and for certification of science teachers.

Our research into the need for a math series and the form it should take has confirmed the sad state of math education in this country. Two salient points underline the situation:

- Between 1960 and 1980, science and mathematics scores dropped. "The mean score on mathematics on the well-known SAT was 502 in 1963 and 466 in 1980."

- ° A recent article citing National Science Foundation data reported that 75% of 1980 high school graduates were unqualified to take college-level mathematics.

Illiteracy, and illiteracy in math and science, is a national fact of life. But for better or for worse there are no television illiterates. Children watch television every day. From six to eleven years old, on average they watch 27 hours per week -- as much, or more, time as most spend in school.

Parents are, and should be, encouraged to limit viewing time of their children. Broadcasters are, and should be, encouraged to reduce violence and other anti-social behavior modelled on television. But it is safe to say that television much as we know it today is here to stay -- and that children are unlikely to turn away from the tube in large numbers.

Our choices are not limited to trying to mitigate the widely perceived bad effects of television for children. Children's television can be constructively educational -- not just the opposite. And our own programs -- SESAME STREET, THE ELECTRIC COMPANY, 3-2-1 CONTACT -- as well as other educational programming, have proved that children will watch and pay attention to educational programming carefully designed and effectively produced for them.

In short, we have in hand a tool -- quality educational television -- that works, and works effectively and economically for millions of children. The NSF-SEE has picked up that tool and put it to work -- first for science and technology, and now for math.

The record shows that this work is desperately needed. Compare, for example, the formal in-school instruction of children in Japan and the Soviet Union with the United States.

In Japan, in grades nine through 12, nearly all college-bound students take three natural science and four math courses. About 30 percent of Japanese high school students have had computer-related instruction by the time they graduate. In the Soviet Union, all children complete a mandatory program that includes 10 years of math, five of physics, four chemistry, five and a half of biology, and five of geology.

In this country, on the other hand, two thirds of all high school students have taken a trivial two years of math by the time they graduate. And only 5 percent receive experience with computers while in high school.

Given the fact that it takes time to train teachers in subjects such as math and science, even introducing a mandatory curriculum will not close this gap quickly. Moreover the fact is that children in this country -- most especially girls and minorities, are uninterested -- turned off -- by math and science by the time they begin high school. Positive motivation, interest and a sense that they can master these subjects needs to occur in late elementary years.

These, of course, are precisely the goals of 3-2-1 CONTACT and our proposed math series. Television can supplement work in the schools, and do things visually in these subjects which most schools simply cannot.

Each week 3.5 million households watch 3-2-1 CONTACT at home. With the combination of some new programs each year and repeat airings of earlier seasons, 3-2-1 CONTACT costs only one penny per person per-viewing.

Children's Television Workshop works hard to ensure that 3-2-1 CONTACT has an impact beyond the screen. Teachers Guides are provided and teacher training workshops conducted around the country. Over 750,000 copies of the Teachers Guide have been distributed so far. Strong participatory activities are taking place with a variety of organizations such as science museums and the Girl Scouts of America. Science clubs for children based on the series are also gaining momentum with club packages and activity guides being provided.

Together with 3-2-1 CONTACT, the new math series will provide a daily hour of science and math education for elementary school age children, and will complement the daily hour of SESAME STREET for preschoolers.

If we are serious about maintaining our competitive edge in the coming decades, we need to give sustained attention to children's television, a readily available means of helping to meet this country's need for high quality, low cost supplemental education, in math and science.

We're concerned about our children -- and we know you are too. It is time to recognize the proven benefits of television as a constructive force. For educational purposes it is highly cost effective and available and appealing to rich and poor, girls as well as boys.

Federal funding is essential to ensure the production of programs such as 3-2-1 CONTACT and our proposed math series. The National Science Foundation stands as a basic funding source for these television efforts in science and math education. With your help they can sustain and build on the progress already achieved.

The NSF's Science and Engineering Education Directorate program merits and needs your continued support.

Colorado State University
Fort Collins, Colorado
80523

Vice President for Research
303/491-7194

February 13, 1986

Congressman Doug Walgren, Chairman
Subcommittee on Science, Research and
Technology
2319 Rayburn Building
Washington, DC 20515

Dear Congressman Walgren:

I would like to submit the following testimony regarding the National Science Foundation budgetary authority for FY 87. We request this entry be made into the official record.

Your cooperation in this regard is very much appreciated.

Very truly yours,

Judson M. Harper
Vice President for Research

:jrb

Enclosure: Mentioned

Colorado State University (CSU) was this country's first university to order and install a supercomputer. Since 1981, CSU has operated a supercomputing center for its own sophisticated research needs and for the benefit of a wide variety of remote users. In 1985, CSU became a NSF Phase I Resource Center which has provided supercomputing resources to a large array of academic researchers.

CSU has been committed to expanding the availability and use of advanced computation in the nation's research and development efforts. We believe computationally-based research stands alongside theoretical and experimental approaches as a third technique to advance our nation's scientific and engineering prowess. And, as you know, scientific advancement spurs our nation's economic development. To support these efforts, University representatives told Congress of the need for special initiatives which would utilize the academic community to develop and enhance advanced scientific and engineering computation. It is from this perspective of demonstrated commitment, action and experience that I wish to address several points about the budget level, direction and priorities NSF's Advanced Scientific Computing efforts.

NSF has had an Advanced Scientific Computing initiative since 1984 and taken several approaches to fill these needs with academic institutions. To satisfy the immediate requirement for supercomputer access, NSF bought time on existing supercomputers to allow researchers to conduct advanced research work. These Phase I Center awards were made to Purdue University, the University of Minnesota, Colorado State University, and three commercial firms. Each of the universities had taken a bold and somewhat risky leadership step by investing vast financial resources and time to be the first to establish supercomputing facilities. In addition to installing the hardware, each institution developed telecommunications, training and other support services necessary to make such facilities available to on- and off-campus users. To date, nearly all the concrete examples of how the supercomputer can beneficially impact academic scientific and engineering research have come from researchers using the Phase I Centers.

In addition to providing supercomputing resources, NSF has recognized the need to develop supercomputer centers of excellence which will maintain state-of-the-art computing hardware, focus on research related to supercomputing, and provide training and education on advanced computational methods. This need is currently being addressed through the awarding of Phase II Centers to the Princeton Consortium, Cornell University, the University of Illinois, and the San Diego Consortium. This group has since been expanded to include the Pittsburgh Consortium, to which NSF gave a Cray I computer to initiate Center activities. NSF's selections represent an impressive potential array of talent and capability. However, none of them had an operating supercomputer or supercomputing experience at the time of the award. In the absence of existing hardware and capability at these Phase II Centers, NSF is providing funding averaging approximately $10 million per year at each of these Centers, with commitments at this level for the next five years. In the long-term, Phase II Centers are to be permanent and the principal source of academic advanced scientific computing research effort for the nation. Researchers located at other campuses remote to these locations will have to communicate with these Centers through high speed data communication systems which have only been rudimentarily defined, and are expected to be available within a three to five year time frame. Further, researchers at remote locations will have difficulty in sharing in the scientific climate at these Centers without traveling to them.

We at Colorado State University question the above approach as the principal mechanism to satisfy the nation's rapidly expanding research needs, which will in turn bolster our nation's economic and strategic capabilities. This approach not only concentrates advanced scientific and engineering computational research at relatively few sites. It does not address the issues of access, regional distribution, and areas of scientific and engineering focus through funding of a greater diversity of Centers.

NSF has announced its plans to purchase more supercomputing time, indicating a recognition of the ongoing need to provide resources by extending the Phase I Center approach. This will continue a needed program. However, it does not recognize that the current academic Phase I Centers are their principal source of training, graduate education, advanced computational research, telecommunications, etc., in contrast to the commercial Phase I Centers that simply provide computing resources. Recognition of these attributes at the current academic Phase I Centers with future funding for them beyond the purchase of supercomputing cycles would greatly enhance the Phase I Centers' role in NSF's program. An expansion of the Phase I Centers' role would increase faculty interest, provide a greater pool of manpower, naturally broaden areas of computationally-based research, encourage greater industrial interest, provide more geographic diversity of supercomputing activity, and increase exposure and usage of a variety of American-built supercomputing hardware.

These proposed positive developments would come at a time when remote accessing of supercomputer resources is inadequate when compared to needs. Time and money constraints do not indicate a timely response to the demands. An increase in the funding of supercomputing activities along with the purchase of resources at Phase I Centers would attract more State matching funding, thus extending Federal resources. Cooperative benefits would accrue to both parties. The cost/benefit ratio for this expanded Phase I approach would be significant in comparison to the planned funding aimed at a few large Phase II Centers which do not have the extensive experience in operating and utilizing advanced computing hardware.

Let me use CSU as an example of the potential benefits NSF would realize under this proposed expansion of activities at the Phase I Centers. NSF would share the benefits and experiences of:

1. The State of Colorado's 56 kB network linking its research universities and its upgrade to T1 speed by 1987 through the assistance of Mountain Bell and U.S. West;
2. A supercomputing applications laboratory having high speed graphics and engineering workstations capability;
3. Its NASA designation as a supercomputing graduate education center of excellence;
4. Having substantial computationally-intensive research in the areas of fluid mechanics, chemistry, image processing, atmospheric science, engineering, and applied mathematics; and,

5. An experienced staff who has a successful record of training, consulting and operation.

Greater support to an expanded Phase I Centers program is necessary for the continuity of funding needed to assure equipment upgrades and commitment to the effort. Such an approach will allow the NSF initiative to build upon existing programs and demonstrated excellence in the advanced computational arena.

Finally, we favor an expanded NSF budget emphasizing support in the area of advanced scientific computing in order for our nation to maintain its leadership in this vital area. This, coupled with a programmatic funding strategy which emphasizes more diversity in the centers of excellence in advanced computing, and increased and improved telecommunications, will serve our nation best at this particular time.

CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS
1200 Seventeenth Street, N.W., Suite 520, Washington, D.C. 20036 • (202) 887-6166

STATEMENT OF THE CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS (COSSA)

Howard J. Silver
Associate Director for Government Relations

on the

FY 1987 BUDGET FOR THE NATIONAL SCIENCE FOUNDATION

Prepared for the
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

The Honorable Doug Walgren, Chairman

March 26, 1986

American Anthropological Association • American Economic Association • American Historical Association • American Political Science Association
American Psychological Association • American Sociological Association • American Statistical Association
Association of American Geographers • Association of American Law Schools • Linguistic Society of America

The Consortium of Social Science Associations (COSSA) represents more than 185,000 American scientists across the full range of the social and behavioral science disciplines. It functions as a bridge between the research world and the Washington community. A list of COSSA Members, Affiliates, and Contributors is attached.

COSSA would like to take this opportunity to comment on the proposed budget for the National Science Foundation (NSF) for FY 1987. The overall increase of 16% over FY 1986 post-Gramm-Rudman-Hollings levels proposed for NSF is indeed welcome in this era of deficit reduction. Maintaining the investment in basic research is essential to the economic competitiveness and security of this nation. Investment by the Foundation in social and behavioral science research demonstrates a recognition of the substantial contributions these sciences make to those important national goals. Reducing this commitment would decrease the quality of our scienctific endeavors and inventiveness.

The 14% increase for Research and Related Activities in FY 1987 over FY 1986 post-Gramm-Rudman-Hollings levels is also welcome. We strongly urge the maintenance of that increase during the Committee's deliberations. Although they are not as substantial as the increases proposed in FY 1986, the increases for FY 1987 in the Division of Social and Economic Science and the behavioral science programs in the Division of Neural and Behavioral Science reflect continued support for these disciplines. We are quite pleased with the substantial increase for the Division of Information Science and Technology where approximately 40% of the awards go to social and behavioral scientists.

We are especially pleased that the social and behavioral sciences will share in some of the special emphases of the Foundation for FY 1987. The Decision and Management Science program's increased funds for risk assessment, the Geography program's increase for computerized mapping and physical geography, and the continued support for more sophisticated computerization of the social and behavioral science data bases, are indications of NSF's involvement of the social and behavioral sciences in its targeted research priorities.

Despite all this pleasure, we are not satisfied. Although, if the FY 1987 proposed funding levels are maintained, the social and behavioral sciences will have finally been restored to their FY 1980 levels in current dollars, support for these sciences at NSF is 27% below the 1980 levels in constant dollars (see Exhibit A). In FY 1987 we remain at only 4% of the NSF research and related activities budget, a figure that has declined over the past four years, and is a full 2% under the FY 1980 share of that budget.

COSSA believes that the Subcommittee should increase funding so that 5% of the Research and Related Activities budget goes to social and behavioral science research. This would mean adding $14 million to the FY 1987 proposed funding. We believe this is a justifiable goal given the intellectual vitality and ferment in these sciences and their importance to the nation.

We are also not satisfied with the small increase for the Directorate for Science and Engineering Education (SEE). For too many years now the Foundation has stalled in supporting a full and vital SEE Directorate. The small increase proposed for FY 1987 comes on top of a deferral of FY 1985 appropriated funds. This Directorate which supports research in teaching and learning and the education and training of new scientists deserves greater support than it is getting from the Foundation.

Mr. Erich Bloch, Director of the National Science Foundation, argues in favor of basic research "as a force for present and future competitiveness" of the United States. It is clear that social and behavioral science research plays a vital role in competing in an international economy driven by science and technology. Economic competitiveness is achieved not only by developing new and better products, but also by understanding how to interact with those products, how to use them, how to manage the people who make them, in other words, the human behavior side of technological advancement. It is in these areas and others that social and behavioral science research offers the nation the resources and results to compete.

A sampling of the scope and nature of work in these sciences indicates the contributions, those already made and those with great potential, that continued and increased support from NSF will foster:

- Advances in theoretical economics and econometric modeling have led to advances in economic forecasting and economic policy. Although, economic forecasting is not perfect, these advances have narrowed the range of disagreement among economists in their ability to help policy-makers. As Herbert Simon has pointed out, the major differences that remain result from different assumptions about how people form expectations, a question that is now the focus of much social and behavioral science research.

- Great advances in statistical techniques, such as multidimensional scaling, have produced sophisticated methods of data analysis. These techniques continue to undergo improvement.

Refinements in survey research methodology will produce more accurate indicators upon which many of our economic decisions are based. The access of social and behavioral scientists to new generations of computers will enhance these activities.

- The need to construct computer models of the international economy to adequately monitor its behavior is another activity where economists are playing a significant role in contributing to U.S. competitiveness.

- The theory of rational-decision making remains one of the major accomplishments of the social sciences in the past. Yet recently social scientists have discovered its limitations. The ability to determine how people, from elite policy makers in government and business to the man and woman in the street, make individual choices will strongly affect how the U.S. fares in this competitive world.

- Advances in cognitive psychology have led to experimentation that helps us understand how people process information and perform complex tasks. These techniques are being applied to important problems in education, business and professional decision-making, and man-machine interaction. All of these are related to keeping America on top scientifically and economically.

- Advances in the study of sensory perception have allowed us to understand how people perceive complex stimuli. The military is particularly interested in auditory and visual perceptions in order for their personnel to operate in multidimensional auditory and visual environments. A modern military reacting positively in complex environments keeps America secure.

- Linguists are working on models, many of them computerized, of how children acquire and transmit their native language. These studies have led to the development of instruction packages, some computer-aided, to teach our children and others the language skills, both native speaking and foreign, that are needed to compete in an international economic setting.

- Keeping Americans healthy and productive is a major factor in maintaining the competitive edge. The work of social and behavioral scientists in relating good heath to behavioral factors has contributed to increased consciousness of how people control their own quality of life. This is especially true in keeping our rapidly aging population active, productive, and free of dependence on costly health care and maintenance.

- Research on criminal careers and career criminals has developed insights into why a portion of the population decides that illegal productive enterprise is more attractive than legal productive enterprise. America loses substantial dollars and sometimes talent to these illegal activities, creating more competitive disadvantages. Understanding why and developing methods to rechannel these activities can lead to more productive lives for these people and safer lives for everyone else.

- Studies of agenda formation and agenda setting in organizations demonstrate the importance of the agenda itself in decision-making. How issues reach the national agenda of government often determines the response to those issues. External challenges often focus our energies more than internally determined responses.

- How the United States competes internationally depends on our understanding of other governments and cultures. Social and behavioral scientists contribute to that understanding by focusing on international aspects of political, economic, and social choices. Evaluating the impact of different electoral systems on policy making, explaining international economic systems, and examining social and cultural differences of foreign nations have long been the purview of social and behavioral scientists.

- Direct utilization of social and behavioral science research on management styles and worker participation has revolutionized the automotive industry in this country. It is a shame that the Japanese and Swedes paid attention to this research earlier than our American companies. As sociologist William F. Whyte notes, it took the shocks of international competition to persuade industrial leaders in the United States of the need to make basic changes based on the organizational behavior literature.

- Research on the interaction between people and technology has led to attempts to revitalize America's shipping and shipbuilding industries. The work of Einar Thorsrud in Norway involving physically re-designing ships and reducing social and status differences among people on the ships, has formed the basis of changes in human resource utilization in the U.S. maritime industry.

- Social scientists are being called upon by State governments to conduct policy research and technical assistance designed to aid in the revitalization of U.S. industry.

- Examining the impact of Employee Stock Ownership Plans (ESOPs) and worker cooperatives is another example of social science research contributing to better understanding of economic productivity to keep this nation competitive.

A briefer sampling of the research in social and behavioral sciences further suggests the vitality and ferment that make support for these sciences so important to continued economic competitiveness. Topics currently being studied include:

- microsimulation models to help target federal funds to those who most need them;
- human adaptation to stressful environments;
- assessment of risks in occupational settings;
- attracting more women and minorities into science;
- developing computerized models of transporting food from surplus areas to deficit regions in countries around the world;
- youth unemployment; female participation in the labor market; why people change jobs;
- economic constraints on single parent households;
- understanding and predicting human responses to natural and technological disasters;
- comparing the largest metropolitan areas of the country concerning urban land use, population distribution, transportation use, and other critical urban functions;
- social components of alcohol and drug abuse;
- decision-making by farmers and their response to the agricultural crisis;
- the impact of different housing arrangements on the elderly;
- the impact of inflation and deflation and other economic changes on American families;
- the cognitive capabilities of very young children and ways to cope with a teacher shortage for this group.

These lists are by no means exhaustive. They are presented to illustrate that these sciences are conducting research into all areas of human activity that affect the current and future productivity and competitiveness of this nation. As we said last year, research in social and behavioral science does not always yield the solution to the problems it investigates, but increasingly it provides decision-makers with the information to make better and more informed decisions.

We would like to thank this Subcommittee for its support of the social and behavioral sciences in the past. We call on you to move toward more equitable support for these sciences by increasing their allocation within the NSF budget.

Thank you for allowing us to present our views.

NOTE:
USED FY82 DOLLARS
FROM FY80 ON

HISTORY OF SOCIAL AND BEHAVIORAL SCIENCE FUNDING AT THE NATIONAL SCIENCE FOUNDATION

	FY80	FY81	FY82	FY83	FY84	FY85	FY86 (EST)	FY87 (EST)
SOCIAL AND ECONOMIC SCIENCES (Current Dollars)	$31.4	$25.1	$17.6	$20.3	$24.6	$28.6	$28.6	$31.4
(Constant Dollars)	$37.1	$26.9	$17.6	$19.5	$22.7	$25.5	$24.7	$26.0
BEHAVIORAL SCIENCES(BNS)*-(Current Dollars)	$21.1	$18.5	$15.0	$16.6	$18.6	$23.3	$21.3	$23.6
(Constant Dollars)	$24.9	$19.8	$15.0	$15.9	$17.2	$20.8	$18.4	$19.6
TOTAL BEHAVIORAL AND SOCIAL SCIENCES-(Current Dollars)	$52.5	$43.6	$32.6	$36.9	$43.2	$51.9	$49.9	$55.0
(Constant Dollars)	$62.0	$46.8	$32.6	$35.4	$39.9	$46.2	$43.0	$45.6
GNP Deflators	0.85	0.93	1.00	1.04	1.08	1.12	1.16	1.21

*Includes psychobiology
Source: NSF Budgets to Congress, FY 1976-1985
12/11/84

EXHIBIT A: Source: The National Science Foundation

Consortium of Social Science Associations

Members

- American Anthropological Association
- American Economic Association
- American Historical Association
- American Political Science Association
- American Psychological Association
- American Sociological Association
- American Statistical Association
- Association of American Geographers
- Association of American Law Schools
- Linguistic Society of America

Affiliates

- American Association for Public Opinion Research
- American Educational Research Association
- American Evaluation Association
- American Society of Criminology
- Association for Asian Studies
- Eastern Sociological Society
- Economic History Association
- Gerontological Society of America
- History of Science Society
- International Studies Association
- Law and Society Association
- Midwest Sociological Society
- National Council on Family Relations
- National Council for the Social Studies
- North Central Sociological Association
- Northeastern Anthropological Association
- Operations Research Society of America
- Population Association of America
- Regional Science Association
- Rural Sociological Society
- Social Science History Association
- Society for American Archaeology
- Society for the History of Technology
- Society for Research in Child Development
- Society for the Scientific Study of Religion
- Southern Sociological Society
- Southwestern Social Science Association
- Speech Communication Association
- The Institute of Management Sciences

Contributors

- University of California, Berkeley
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- Carnegie-Mellon University
- Center for Advanced Study in the Behavioral Sciences
- Center for International Studies, Duke University
- University of Chicago
- University of Colorado
- Columbia University
- Cornell Institute for Social and Economic Research
- Cornell University
- Florida State University
- Harvard University
- University of Illinois
- Indiana University
- Institute for Research in Social Science, UNC-Chapel Hill
- Institute for Social Research, University of Michigan
- University of Iowa
- The Johns Hopkins University
- Massachusetts Institute of Technology
- Maxwell School of Citizenship and Public Affairs, Syracuse University
- University of Michigan
- University of Missouri
- University of Nebraska
- New York University
- University of North Carolina, Chapel Hill
- Ohio State University
- University of Pennsylvania
- Pennsylvania State University
- University of Pittsburgh
- Princeton University
- Rutgers University
- Social Science Research Council
- University of Southern California
- Stanford University
- State University of New York at Stony Brook
- University of Tennessee, Knoxville
- Texas A & M University
- Tulane University
- University of Washington
- University of Wisconsin, Madison
- University of Wisconsin, Milwaukee
- Yale University

FEDERATION OF BEHAVIORAL, PSYCHOLOGICAL AND COGNITIVE SCIENCES

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TESTIMONY OF

Federation of Behavioral, Psychological and Cognitive Sciences

on the subject of

REAUTHORIZATION OF THE NATIONAL SCIENCE FOUNDATION

prepared for

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

The Honorable Doug Walgren, Chairman

March 14, 1986

American Educational Research Association • American Psychological Association • Cognitive Science Society • Human Factors Society •
International Society for Developmental Psychobiology • National Academy of Neuropsychologists • Psychometric Society • Psychonomic Society •
Society for Computers in Psychology • Society for Mathematical Psychology • Society for Psychophysiological Research •
Society for Research in Child Development • Society of Multivariate Experimental Psychology

This statement is prepared by the Federation of Behavioral, Psychological and Cognitive Sciences. The Federation, established in 1980, is a coalition of 13 scientific societies with combined memberships of over 90,000. The Federation's interests include research on behavioral, psychological and cognitive processes and their physiological bases and its application to education, health and human development. We are pleased to comment for the record on the reauthorization of the National Science Foundation.

As scientists we are pleased with the Administration's active support of Federally funded basic research, as reflected in the proposed NSF FY87 budget. It is important to the nation to maintain a strong Federal role in basic research even as the Congress is making major steps to reduce the Federal deficit. In fact, consistent funding for NSF, whose sole mission is to support basic science, now is more important than ever.

Research results cannot be bought on a short time scale. Neglecting basic research this year means fewer gains in subsequent years. We will not be able to remedy this deficit by increasing research spending at that later time. Good research requires attracting good people to work on important problems, training new researchers, obtaining basic results and working out their applications. None of this can be done quickly; the investment in ideas, methods, and applications must be made now. That is why it is important for the government to maintain and enhance, wherever possible, its support for basic research.

In this testimony we would like to call to the Subcommittee's attention the critical importance of research in the behavioral and cognitive sciences and science education.

Behavioral and Cognitive Sciences

The human mind is really our biggest economic resource. The prospects of increasing human productivity lie in improving the productivity of the human mind. One way is by using technology to augment human thinking. Another is through research on cognitive processes, which has the potential of enhancing our own abilities to think and solve problems and to improve education and training.

The nation faces serious difficulties in adjusting to new information technologies in the work place and in finding productive ways to utilize new technologies to increase the productivity of our industrial and educational institutions. Results of research in behavioral and cognitive sciences are already being used in the design of new human-machine systems, the development of programs of training and education and the improvement of the working environment for many in our nation's work force.

Traditionally one thinks of automation in terms of job productivity and job availability. However, automation affects the role of the supervisor of complex equipment and systems. Examples are airline pilots, power plant control room operators or intensive care nurses. These jobs can shift from boring (when everything is running smoothly under computer control) to overwhelming (during an emergency) in brief periods of time. Technology assists in performance, but it raises a new set of issues: Should systems make their own decisions? Should they inform the operator of every action they take? Do these systems create or eliminate workload? Much of the basic research that will help answer these questions is in the areas of decision making, problem solving, perception and motor skills.

Continued improvement in the use and development of technology requires solutions of fundamental scientific problems regarding the nature of human understanding, learning and motivation. We need to understand more about the cognitive skills and knowledge required for successful performance in technical domains. We need to study how people understand technological systems in order to assure an optional design for human use and comprehension. As we become increasingly dependent on electronic graphics for communication, scientific progress in understanding thought processes will contribute critically to the design of computer-based visual displays. Characterizations of the mental models that people use in reasoning provide a basis for better design of technical information systems and training in the use of technical systems.

In addition, recent basic research on visual perception and attention and spatial orientation is now changing, for example, our understanding of nighttime driving. These results have implications for driver education, night driving speeds, and headlight and highway lighting requirements.

How do people rapidly identify the meaning of a visual symbol? Perhaps more interesting, why is it that people who have large vocabularies are quicker at recognizing simple words? What sort of information retrieval system gets better as its data base increases? Substantial advances in our understanding of word recognition are made by exploring computational parallels of the process. An area of increasing importance is psychobiology, an area which links research in brain processes with our understanding of behavior. Fundamental insights into the biological basis of memory, for example, can be expected in the coming years.

Science Education

The need for strengthening our nation's educational programs in mathematics, science and technology is broadly recognized. In turn, this means that we need to improve our understanding of the processes of problem solving, comprehension, learning, teaching and testing to guide the development of new educational resources, including the effective use of new computational technology in both instruction and testing.

It is clear that effective science education will result only from the efforts of both the science and education communities. We support interdisciplinary research efforts by behavioral and cognitive scientists, content area scientists and science educators.

Research on problem solving has provided significant new information about cognitive processes and knowledge--demonstrating the kinds of knowledge required for successful problem solving and providing explicit descriptions of knowledge relevant to selected domains in science and mathematics. For example, a predominant view underlying current curriculum design and teaching in science is that students' understanding of scientific concepts is shaped by their instruction. Much care is taken to avoid presenting incorrect principles or concepts. However, students begin their study with strongly held conceptions of phenomena that are explained by scientific principles. Even young children are curious about their world--how things work as well as their classification. When children do not receive much formal science education until high school or college, misconceptions of scientific concepts are allowed to develop. Research shows that their preconceptions are often inconsistent with the principles to be learned but persist even after considerable instruction. As a consequence, students may be able to use their formal knowledge to correctly solve textbook problems but still base their understanding of events of the world on their incorrect preconceptions when taught with commonly used methods.

Many of the research findings are important for educational practice. Recent information about the sources of difficulty in understanding mathematical, scientific and technical concepts provides a basis for development of educational materials and methods for reaching a broader group of students. Research to identify factors contributing to relatively low levels of participation in mathematics and science courses by women and members of minority groups is underway and is suggesting ways in which increased participation can be developed.

Research in cognitive science is not only changing our views of how people learn science and mathematics, it is also shaping a theory of learning in which content plays a central role. The approach implies that much of the research in teaching and learning in science will be done in the context of the science being taught.

As with any science, research relevant to education in mathematics, science and technology is cumulative. It requires continuing support if it is to sustain and expand its impact in education. Continued NSF support is therefore critical.

Conclusion

We recommend that you continue to support fundamental science research by reauthorization of NSF funding at the level of the Administration's FY87 budget. This is the minimal amount necessary to insure building on your previous investment.

The Federation appreciates the opportunity to submit these comments. We also appreciate the Subcommittee's major role in the recovery of behavioral and social science funding at NSF. Please do not hesitate to call on the Federation staff if we can be of further assistance during your deliberations.

GLCA

GREAT LAKES COLLEGES ASSOCIATION 220 COLLINGWOOD, SUITE 240, ANN ARBOR, MICHIGAN 48103 (313) 761-4833

March 27, 1986

The Honorable Doug Walgren
Chairman, Subcommittee on Science,
Research and Technology
House Committee on Science and Technology
Attn: Bob O'Neill
2319 Rayburn House Office Building
Washington, DC 20510

Dear Representative Walgren:

You may remember that during the question-and-answer period following the testimony of the panel on which I appeared before your Subcommittee in hearings on authorizations for the National Science Foundation, you asked my opinion about set-asides, specifically a fifteen per cent set-aside for something like facilities.

My answer was one of qualified support; that in some special circumstances a set-aside might be the "easiest way to ensure a sector is not neglected," that it "allows a foot in the door."

It has occurred to me that your question might have been addressed specifically to the provisions of H.R. 2823, Mr. Fuqua's "University Research Facilities Revitalization Act." After again reviewing the provisions of that bill as they apply to the National Science Foundation, I would like to expand on my response to your question.

As I said in my testimony, Federal support for research facilities is not a high priority for undergraduate institutions. We consider NSF support for undergraduate instructional instrumentation, undergraduate student research participation and undergraduate faculty development activities much higher priorities.

There are certain problems with the set-aside in H.R. 2823 as it is now written. We understand the "smaller" institutions set-aside for NSF now provides:

> At least fifteen per cent of the amount which is required [to be spent in Federal support of facilities] . . . to carry out the Foundation's university research laboratory modernization program in any fiscal year . . . shall be available only for awards to universities and colleges that received less than **$10,000,000** emphasis added in total Federal obligations for research and development [including obligations for this university research laboratory modernization program] in each of the two preceding fiscal years.

ALBION • ANTIOCH • DENISON • DEPAUW • EARLHAM • HOPE • KALAMAZOO • KENYON • OBERLIN • OHIO WESLEYAN • WABASH • WOOSTER

While all of the non-Ph.D.-granting institutions in the country would fall into the fifteen per cent category, so would almost the entire universe of colleges and universities! NSF representatives reported to a group of higher education representatives in fall, 1985, that forty-seven per cent of NSF funds go to ten institutions that get $10.0 million or more in grants from NSF. The $10.0 million NSF cut-off in H.R. 2823 is also significantly higher than that of the other Federal agencies covered by the bill.

We believe the percentage and threshold provisions of the Fuqua bill should be rethought and probably reformulated before the bill takes a final form if it is intended to serve any more than a few institutions.

Sincerely,

Jon W. Fuller
President

JWF/vbu

BEST COPY AVAILABLE

The MATHEMATICAL ASSOCIATION of AMERICA
INCORPORATED

Lynn Arthur Steen
President

Department of Mathematics
St. Olaf College
Northfield, Minnesota 55057
507 663-3114

March 3, 1986

Congressman Doug Walgren
Committee on Science and Technology
United States House of Representatives
Rayburn House Office Building, Suite 2321
Washington, D.C. 20515

Dear Representative Walgren:

At last week's NSF authorization hearings you asked panelists whether they were optimistic about the future, whether the U.S. government is doing what it must do to insure strength in science and technology for the next 5-10 years. Ed David expressed concern that "big science" might smother the inventiveness that comes from individual investigators--especially in mathematics. I'm concerned, in addition, that despite the importance of mathematics as the foundation discipline for science and technology, the United States faces in the next decade a serious shortage of mathematically competent persons for industry, teaching, defense, and research.

The most serious long-term problem is a shortage of enthusiastic and first-rate mathematics faculty caused by the rapidly growing industrial demand for a declining number of mathematics graduates. The enclosed documents elaborate on faculty shortages and related issues concerning the status of collegiate mathematics: a recent report on the current status of collegiate mathematics, my statement to the National Science Board's committee on undergraduate science, and a proposal to the National Research Council for a major study of collegiate mathematics (referred to on page 7 of Ed David's presentation to your committee).

I believe you will find in these documents compelling evidence of the need for a special review of the role of mathematics in national science policy. I urge you to take Ed David's suggestion and establish a special dialogue with representatives of the mathematics community. The Mathematical Association of America is eager to participate in this endeavor.

Sincerely,

Lynn A Steen

Lynn Arthur Steen
President

LAS:mkp
enc.:

Renewing Undergraduate Mathematics

by Lynn Arthur Steen

Undergraduate mathematics is a major educational conduit for our nation's scientific personnel—not only for future engineers, physicists, and mathematicians, but also for computer scientists, statisticians, school teachers, physicians, economists, and business executives. Some type of undergraduate mathematics is required for virtually every scientific and engineering degree. Undergraduate mathematics is to scientific research what basic research is to applied science, the supplier of intellectual resources.

As science changes, so also must the pattern of undergraduate mathematics. On top of this, mathematics itself is changing dramatically—in content, scope, and application. Powerful and ubiquitous new applications signal to the educated public that mathematics is no longer, if it ever was, the sterile, ethereal, axiomatic exercise of journalistic caricature. The truth is that mathematics is not just being applied, but is being continually created in response to challenges from science, from technology, and from other parts of mathematics itself.

Although new courses such as data analysis, operations research, and discrete mathematics are finding their place in the curriculum, very few courses in the typical undergraduate program give students a realistic sense of the true nature of contemporary mathematics, either pure or applied. Unlike their peers in the natural sciences, undergraduate mathematics students rarely move beyond classroom exercises involving mathematics that is several decades (or even centuries) old. Prevented by curricular constraints from seeing how mathematics is created, students too often view mathematics only as a powerful but static collection of tools to be learned (or worse, memorized) and then applied. They fail to see career options in a field that is presented as a *fait accompli*.

Undergraduate mathematics bears major responsibility for the future well-being of American society. Collegiate mathematics must provide courses for future scientists, programs for prospective elementary and secondary school teachers, remedial courses for those entering college unprepared in mathematics, general education courses for students not majoring in a quantitative discipline, strong majors for those intending to enter graduate school, and a variety of service courses ranging from elementary statistics to advanced operations research. Moreover, in many institutions, mathematicians must also teach computer programming and elementary computer science.

Lynn Arthur Steen of the Department of Mathematics, St. Olaf College, Northfield, Minnesota 55057 currently serves as President of the Mathematical Association of America (MAA). This paper has evolved from presentations made by Steen at several meetings and from ideas provided by the Committee on the Status of the Profession.

As mathematics needs to be continually created to provide new tools for science and industry, so the undergraduate curriculum needs to be continually renewed to reflect the changing nature of mathematical practice and scholarship. Yet the limited resources of undergraduate mathematics departments are now thinly spread over an enormous variety of elementary service courses, leaving virtually no time or energy for the in-depth study necessary to renew faculty initiative or to develop innovative programs.

Signs of distress are not hard to find. The number of degrees awarded in mathematics is only about half of what it was ten or fifteen years ago. Enrollments at the elementary level are double what they used to be, and faculty work loads have increased significantly. Demand for computer science is distorting enrollments and depleting the pool of young prospective mathematicians. Dual salary scales are demoralizing faculty at the same time as budgets for library resources and travel are diminishing.

It is time for the mathematical community—researchers, teachers, and users—to join in a common cause to renew undergraduate mathematics. We need to do more than stimulate the curriculum. We must examine and respond to the realities of student interests and preparation. We must articulate standards for the profession that will enhance the morale and effectiveness of college mathematics teachers. Most importantly, we must engage ourselves and our students in the excitement of creative mathematics applied to challenging scientific and societal problems.

Students

Any analysis of undergraduate mathematics must begin with informed knowledge of our students, who arrive in college having studied mathematics in some form for most of their school years.

Reprinted from the *Notices*, August 1985
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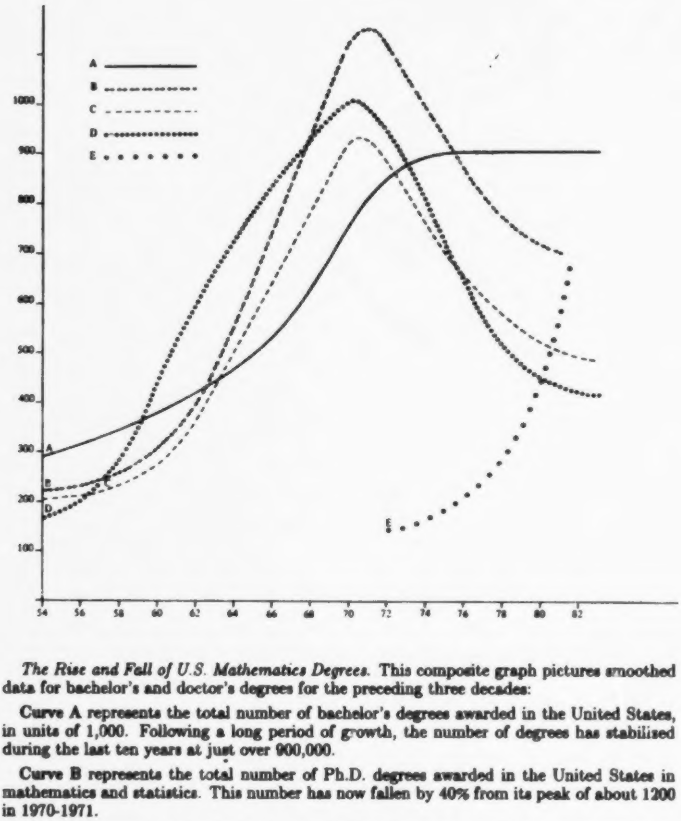

The Rise and Fall of U.S. Mathematics Degrees. This composite graph pictures smoothed data for bachelor's and doctor's degrees for the preceding three decades:

Curve A represents the total number of bachelor's degrees awarded in the United States, in units of 1,000. Following a long period of growth, the number of degrees has stabilized during the last ten years at just over 900,000.

Curve B represents the total number of Ph.D. degrees awarded in the United States in mathematics and statistics. This number has now fallen by 40% from its peak of about 1200 in 1970-1971.

Curve C represents the number of U.S. citizens who received a Ph.D. in mathematics or statistics. As a percent of the data represented by Curve B, it has fallen from about 90% to just under 60%.

Curve D represents the total number of U.S. bachelor's degrees in mathematics, in units of 25. This number also peaked in 1970, at about 25,000; now it has dropped to half that leve

re E, also in units of 25, represents the growth of bachelor's degrees in computer and information sciences. This curve crossed Curve D, the bachelor's degrees in mathematics, in 1980.

The effect of this study is to add to the already great natural variance in mathematical aptitude an enormous variance in both competence and attitude. The latter two characteristics frequently overwhelm the former, and the three together produce a diversity in performance that is almost beyond comprehension: the range of mathematical performance of college freshmen spans ten years of education (grades 7–16), but the distribution is skewed decidedly towards the lower half of this range.

There are approximately four million persons in each age cohort among students of school age; that is a bit more than 1/70th of the total U.S. population. Nearly 30% do not graduate from high school. (The percent of students who finish high school has been declining slightly for the past twenty years, after increasing steadily for the past century.) Of the three million persons who do graduate, about half, approximately 1.5 million, enter college.

About two-thirds of those who enter college have not studied precalculus mathematics. This means that each year about one million students enter higher education without having completed the full program of high school mathematics. Half of those have taken a second algebra course, the other half have not. Thus half a million college students—those who never took Algebra II plus many of those who forgot most of what little they may have learned in that course—enter college needing extensive review of elementary algebra, sometimes including what is euphemistically called "arithmetic for college students."

The best-prepared third of college freshmen, another half a million, are well prepared for college mathematics courses. Approximately 20%, or about 100,000, have actually taken calculus. These represent the top 3% of high school seniors, yet only about one-fourth of those learn enough calculus in high school to receive college credit for the course. Results released at the end of 1984 from the Second International Assessment of Mathematics show that U.S. high school students who have taken calculus score barely above the median when compared to the top 10–15% of students from other countries.

Here is a tabular estimate of the mathematics placement of 18 year old students in the United States:

30%	Do not finish high school
35%	Finish high school; do not go to college
12%	Enter college needing elementary algebra
10%	Enter college ready for precalculus
10%	Enter college ready for calculus
2%	Enter college having completed some calculus
1%	Enter college with some calculus credit
100%	

Last year the National Institute of Education released a report called *Involvement in Learning: Realizing the Potential of American Higher Education.* This report highlights two other student characteristics that are crucial to an understanding of the total undergraduate environment: 40% of all students study part-time, and 40% of all students are over the age of 25. Undoubtedly there is a large overlap between these two groups. And since their impact on undergraduate enrollments is weighted by the part-time nature of their study, the overall impact on enrollment patterns is far less than 40%. But as people, as decision makers, and as voters, these older part-time students represent an important fraction of the individuals studying undergraduate mathematics.

Enrollments

Enrollment patterns in mathematics are difficult to find and interpret, partly because the mathematics profession does not spend much of its resources in keeping track of such data. By interpolating among several sources, I made the following estimates of the distribution of enrollments (in thousands) in beginning college mathematics courses:

%	Enrollment	Course
22%	700	Remedial
18%	600	Calculus
18%	600	Programming
16%	500	Precalculus
13%	400	Elementary Statistics
5%	150	Finite Mathematics
3%	100	Computer Science
3%	100	Discrete Mathematics
2%	50	Mathematics Appreciation
100%	3200	Total

(For check-point comparison, American Mathematical Society (AMS) data for 1983 indicates a total fall enrollment in mathematics and statistics courses of 2.4 million. The table above includes computer programming and elementary computer science, which about accounts for most of the extra enrollments. Since computer courses are taught in both mathematics and computer science departments, it is very difficult to account precisely for the impact that undergraduate computer courses have on mathematics enrollments. The estimate above is primarily for those computer courses taught by or in mathematics departments; it does not count computer science enrollments in departments that are totally separate from mathematics.)

In contrast to the total enrollment of about 3 million in elementary courses in the mathematical sciences, the total enrollment in advanced (postcalculus) undergraduate mathematics is only about 200,000, two-thirds in applied analysis (differential equations and related subjects), one-third in other parts of core mathematics. In other words, over 90% of the enrollments in undergraduate mathematical science are in lower division service courses.

Much of this service load is of recent origin, driven by a society convinced that mathematics, in modest doses, is useful, and perhaps even profitable. These pragmatic forces have reshaped the whole undergraduate culture: in the last fifteen years or so, the number of bachelor's degrees awarded in the arts and sciences has declined by about 50%, while the number awarded in job-related fields has more than doubled. Whereas at the end of the 1960s bachelor's graduates roughly were divided equally between those in arts and science and those in specialty programs, now only about 20% of graduates are in the arts and sciences.

These changes have had a significant impact on enrollment patterns in mathematics. Indeed, in the past fifteen years undergraduate mathematics enrollments in the mathematical sciences have increased twice as fast as has the general undergraduate population, but this increase has occurred totally in the elementary part of the curriculum:

	1970	1985	%
Remedial & Precalculus	800	1800	
Calculus	450	600	
Computer Programming	50	600	
Advanced Mathematics	300	200	
Total Mathematical Sciences	1600	3200	100%
Total B.A. Degrees	780	930	20%
Total F.T.E. Undergraduates	6700	9500	42%

Graduates

About two-thirds of the students who enter college actually graduate: each year there are just under one million bachelor's degrees conferred in the United States. Of these, about 1% are in mathematics, that is, about 10,000. (Here mathematics includes statistics, but not computer science.) About twice that number are now receiving bachelor's degrees in computer and information sciences. In 1970, there were about 30,000 bachelor's degrees in the mathematical sciences awarded in the United States — 90% (27,000) in mathematics, 10% in computer and information science. Since then mathematics degrees have steadily declined and computer science degrees have steadily increased, with the total staying relatively constant. Now there are about 11,000 bachelor's degrees in mathematics, and over 20,000 in computer science.

As bachelor's degrees in mathematics have declined, so have Ph.D. degrees. But even more important, the percentage of U.S. citizens receiving the Ph.D. in mathematics has also declined, from about 80% to under 60%. This has led to a compound decrease of about 50% in the number of Americans receiving doctoral degrees in mathematics. In fact, the number of degrees to U.S. citizens in core mathematics is now as low as it was in the 1960s. Here is a comparison, in round numbers:

	1962		1972		1982	
Mathematics Ph.D.'s	Total	U.S.	Total	U.S.	Total	U.S.
Core Mathematics	400	370	920	720	510	310
Applied Mathematics	50	40	120	100	120	80
Statistics	50	40	150	110	150	90
Mathematics & Statistics Total	500	450	1190	930	780	480
Computer Science	–	–	170	130	260	.60
Mathematical Sciences Total	500	450	1360	1060	1040	640

Faculty

There are currently about 25,000 full time mathematics faculty members in United States institutions of higher education. One fourth are in Ph.D. granting institutions, one half in master's and bachelor's degree institutions, and one fourth in two year colleges. In addition, there are another 20,000 persons who teach mathematics part-time: 9,000 in the two year colleges, 5,000 in the four year institutions, and 6,000, mostly teaching assistants, in the universities.

About two-thirds of all full-time mathematics faculty hold doctoral degrees. In 1965 only 35% of the faculty appointments at the four-year colleges were filled by persons with a doctorate; that percentage has now doubled, partly in response to a national effort in the late 1960s to improve faculty credentials in mathematics. The large load of precalculus instruction coupled with increasing demand for computer science instruction — where Ph.D. degrees are rare — suggests the current percentage of Ph.D. faculty may represent a stable long-term balance of faculty preparation with teaching needs.

	Mathematics Faculty			
	2 Year	4 Year	Ph.D.	Total
Full Time	6,000	12,000	7,000	25,000
Part Time	9,000	5,000	6,000	20,000
F.T.E.	8,000	13,000	9,000	30,000
Ph.D.	1,000	8,500	7,000	16,500
% of F.T.E.	15%	70%	100%	66%
Total Faculty	15,000	17,000	13,000	45,000

For comparison, the U.S. membership in the Mathematical Association of America (MAA) is about 18,000, and in the AMS about 14,000; together, about 25,000 U.S. residents belong to one or the other of these major professional mathematics societies. That is more or less the same as the total full-time mathematics faculty, although of course neither group is quite identical with the other.

The age distribution of the mathematics faculty is very uneven: 20% are older than fifty-five; 50% are between forty and fifty-five; only 30% are younger than forty. Far from being uniform, the age distribution of the mathematics faculty is almost bell-shaped. Just from the Ph.D. faculty alone, there will be 200 retirements per year for the next few years, rising to about 400 per year by the year 2000. Overall, higher education has to replace over 3000 Ph.D. mathematicians during the next fifteen years, about half of what will be produced at present rates.

Recent AMS data shows that only two-thirds of the new doctorates accept first jobs in colleges or universities. The median starting salary for such academic positions is $23,000. The undergraduates that these new Ph.D.'s teach, leaving college with only a bachelor's degree, receive median starting (12 month) salaries of $23,400. The corresponding salary to a new mathematics Ph.D. in industry is about $36,000.

Finally, I note that the "David Report", *Renewing U.S. Mathematics* (National Academy of Sciences, 1984) [reprinted in the *Notices*, August 1984, pages 435–466; October 1984, pages 570–616] documents U.S. plans to introduce several hundred supercomputers during the next decade into academic, industrial and government facilities. Each such machine requires, on average, about a dozen mathematical scientists with sophisticated knowledge of the mathematics of computation. Several hundred such machines will require several thousand new mathematicians. The implications of this demand for the supply of undergraduate faculty are staggering.

Undergraduate Mathematics

The mathematics covered these days in typical undergraduate programs can be divided roughly into three parts: the elementary, the old-fashioned, and the experimental. That may sound unfair, and it may be; but it has a grain of truth. As enrollment data shows, many courses are really not appropriate to collegiate level instruction. Many others frequently contain little or no hint of modern mathematics. And the rest are new courses whose contribution to a unified curriculum is totally untested.

We need courses like these. We need elementary courses to meet students on their own terms; we need traditional courses to convey the classics of mathematics; and we need experimental courses to probe for new areas worthy of undergraduate study. But the nature of contemporary mathematics demands something more.

In an essay titled "Ordering the Universe: The Role of Mathematics," an appendix to the David Report, Arthur Jaffe writes about the enormous breadth of modern mathematics, pure and applied. Here is a sample from his survey:

- Fourier analysis, from fast Fourier transform to pseudodifferential equations;
- Simple groups and number theory, applied to algorithms and computational complexity;
- Numerical mathematics, used for nuclear reactors and computerised tomography;
- Compact groups, used in mathematical physics to represent quarks and supersymmetry;
- Fibre bundles and connections, used for gauge theory in electrodynamics;
- Poincaré conjecture, in four dimensions, yielding exotic Euclidean spaces and explanations of solitons;
- Algebraic geometry, applying the Riemann-Roch theorem to generate error-correcting codes;
- Time series analysis used for seismic exploration for oil;
- Chaotic behavior in dynamical systems, related to the onset of turbulence as well as to the theory of fractals;
- Parallel computation and unbounded memory, suggesting radically new algorithms for numerical mathematics

This list of current mathematical research topics is neither elementary, nor old-fashioned, nor experimental. It consists of classical mathematics—analysis, algebra, topology—mixed heavily with physics and engineering, employing modern computer tools to model significant scientific phenomena. It shows a vigorous science rooted in the rich soil provided by generations of mathematical giants.

We cannot teach all this mathematics to undergraduates. But we must, somehow, teach the foundations of this mathematics, while at the same time providing glimpses of the structure that this foundation can support. To do that will require a new synthesis of classical and modern topics, not merely the unstructured aggregation of traditional courses with experimental alternatives.

It is not my intent here to discuss the many curricular changes affecting undergraduate mathematics. The enrollment patterns cited above indicate the extent to which the rushing waters of mathematics have moved from a narrow deep gorge to a flat broad plain. Twenty years ago the Committee on the Undergraduate Program in Mathematics (CUPM) helped guide the undergraduate curriculum to a stable consensus on a core of undergraduate mathematics. Today that consensus is shattered: in its most recent statement CUPM reported that there is no longer any consensus on specific advanced subjects that should constitute the core of undergraduate mathematics.

Mathematics is not the only discipline suffering from a dissolution of consensus on purpose and direction. A recent report by the Association of American Colleges (AAC) called *Integrity in the College Classroom* decries what it calls the "decline and devaluation" of undergraduate education: "A consequence of the dispersal of authority over the curriculum is... unhappy disarray, the loss of integrity in the bachelor's degree." The AAC report cites the narrow graduate-school professionalism of faculties as the root cause of the identity crisis in undergraduate teaching, and seeks "to revive the responsibility of the faculty as a whole for the curriculum as a whole."

Mathematics is a party to the decline of undergraduate education, sharing both in responsibility for the decline as well as in its consequences. What used to be a focused albeit narrow curriculum is now too often a smorgasbord of unrelated courses. As demand for new applications proliferate, the focus of the undergraduate curriculum disintegrates. In many departments mathematics faculty now devote more teaching effort to computer programming than to calculus.

This curricular change is a two-edged sword. While it has diminished the strength of traditional core mathematics—what most of us were trained in during our graduate studies—it has at the same time multiplied the linkages between mathematics and other disciplines. No longer are the concepts of mathematics only used in physics and engineering. Now they can be found in linguistics, medicine, psychology, agriculture, music—virtually every subject taught in an undergraduate curriculum. The connections between mathematics and other subjects are often mediated by computer science, but real mathematics lurks immediately beneath the surface. Although most of us do not yet realise it, and many may not even welcome it, the mathematics faculty has within its discipline a legitimate responsibility for linkages to the whole undergraduate curriculum. Mathematics as a discipline is uniquely positioned to help play a major role in the renewal of undergraduate education.

Teaching and Research

The renewal of collegiate mathematics will require imaginative effort in curricular reform, both within the mathematics major and in various interdisciplinary programs. It will require exciting new approaches that attract the best young minds of the next generation, as well as a continual struggle to encourage good students to pursue graduate work in the mathematical sciences. But most of all, it will require sound and productive programs of faculty evaluation and faculty development for those 25,000 members of our current mathematics faculties.

In every field, the vitality of undergraduate education depends on effective links between teaching and research. Such links are especially important in mathematics, because the field is changing so rapidly. They are also especially difficult to form, since the frontier of mathematical research is so remote from the reality of undergraduate courses. The links between teaching and research in mathematics are long, fragile, and easily broken. Especially for this reason, the relation between teaching and research is an important and crucial aspect of faculty renewal and faculty evaluation.

Renewing U.S. Mathematics calls for vast increases in support for mathematics research, especially in the leading Ph.D. granting institutions: "The health of the mathematical enterprise in the United States hinges on the strength and vitality of the departments in the leading research universities." This report also contains a careful analysis of research productivity in the mathematical sciences, cross-checked in several different ways. It concludes that the number of productive research mathematicians is about 3,000, including 2,600 established and 400 young investigators. One measure of "productivity" was three papers in five years that were reviewed in *Mathematical Reviews*; another was peer review that judged their work equivalent to that already being supported through National Science Foundation (NSF) and Department of Defense (DOD) research grants. It is clear from this study that only a small minority—about 10% of the total, or 20% of the Ph.D. holders—of U.S. mathematics faculty are productive researchers according to these criteria. This observation has important implications for faculty renewal and faculty evaluation.

Every college and university sets standards of professional work for permanent members of its faculty. Research universities usually have three distinct missions: teaching, research, and service; faculty responsibilities at these institutions parallel the mission of the institution, requiring significant contributions in each area for its own sake.

The majority of post-secondary institutions, however, define teaching as their primary mission. Yet even most of these institutions, at least all the four year institutions, require significant professional activity of faculty to insure that they remain intellectually alive and actively in contact with their discipline. The vast majority of faculty at these schools engage in research and professional activity not so much to advance the frontiers of research as to maintain their vitality as teachers and to provide, by example and by experience, a context in which their students can taste the excitement of creative mathematics. It is this aspect of professional work that is especially important in mathematics, yet too often overlooked in faculty tenure and promotion reviews.

The relation of teaching to research in mathematics is crucially important and virtually unique among undergraduate disciplines. Professional activity is enormously important in mathematics because of the rapid growth of the mathematical sciences. Teaching that is divorced from professional activity may be effective and popular, but it cannot long remain intellectually honest. The only way for a curriculum in the mathematical sciences to remain current is for the faculty to remain professionally active.

For too long mathematics and mathematics teachers have suffered from a rigid, narrow definition of professional activity. To save face with our peers in the sciences and humanities, we expect of ourselves a productive research program; to save face with our peers in mathematics, we adopt the mathematician's elite definition of research. The result too often is confusion, frustration, and well-intentioned hypocrisy in faculty tenure and promotion proceedings.

Morris Kline argued forcefully in his provocative 1977 book, *Why the Professor Can't Teach*, that mathematics must re-establish respect for scholarship, for research in its traditional meaning. In this view, a teacher's time and energy should be devoted both to instruction and to that kind of scholarship which is the complementary aspect of good teaching. The breadth of the mathematical sciences, the importance of renewed links between teaching and research, the rapid creation of new mathematics, as well as the David report's conclusion that only 10% of college mathematicians are productive researchers—these and other signs suggest that it is time to establish a new definition of professional work for college mathematicians.

Professional Work in Mathematics

Professional work in mathematics, as in any field, must be public—that's the root of the word "publication." But it need not be restricted to narrow, traditional research publications. It should embrace all published works (texts, research papers, reviews, expository articles, classroom notes), presentations at meetings and at other institutions, leadership in professional organizations, arranging professional workshops, and consulting for government, industry or academic institutions. The important common element is the scrutiny and review afforded by public presentation: this is vital to both the individual and the institution as an external measure of the significance of the work. Moreover, public presentation imposes on the individual a healthy discipline in organizing ideas and thinking systematically about key issues in the mathematical sciences.

The creation of new mathematics expresses as nothing else can the fundamental processes of mathematics, and an active research program in a department can help stimulate not only new ideas but also new modes of thought. But it is not something we can demand as a *sine qua non* for either promotion or tenure. It is, rather, one option among many.

To balance my appeal to authority, I add supporting evidence from Peter Hilton, who once wrote a scathing review of Kline's book. But on this issue they seem to agree: "I believe," writes Hilton, "that promotion and tenure should be the reward of outstanding work of an imaginative and innovative nature. Such outstanding work could be in the field of mathematical research, but does not have to be. Thus it is perfectly possible and, today, more important than ever, to show imagination, energy and enterprise in the development of new courses and the modernisation of old ones."

Directly or indirectly, all professional activity relates to teaching. Teachers who are active imbue their courses with a spirit of current thought. Yet only rarely in mathematics will the content of significant research translate into material suitable for undergraduate instruction. It is in this respect that mathematics differs from most other fields. A Shakespeare scholar can relate current research to undergraduate courses, as can a biochemist studying techniques of recombinant DNA. But the mathematician working on shock waves or gauge fields cannot readily relate this work to any typical course in the undergraduate curriculum. However, the process of mathematics is continually renewed by professional activity, and it is the process more than the content that matters in effective teaching.

The gulf between undergraduate instruction and mathematical research is much easier to span in the newer applied subjects than in traditional core mathematics. These subjects appeal to students not only because they are new and applicable, but also because they are near the frontier. Undergraduates need to experience the euphoria of discovery in order to taste the true nature of mathematics. The ability of instructors to lead students to the brink of unsolved problems in these newer areas is in itself a substantial reason to emphasize these topics in the undergraduate curriculum. Moreover, what is good for students is also good for the faculty: interdisciplinary work applying mathematics to problems in other fields provides a marvelous opportunity for college mathematics teachers to become professionally active.

Typically, the links between scholarship and teaching that emerge in mathematics relate to development of new courses or entire new curriculum structures, to the integration of computing and applied techniques into traditional mathematics, to supervision of independent study in areas that reach into unfamiliar territory, to development of innovative curriculum materials for new courses, or to development of computer software and documentation. In cases such as these, professional work is often focused on local issues and, for this reason, may not lead to significant public exposure. It is, nevertheless, important for the department and for the individual.

We, the mathematical community, must work to establish effective mechanisms to evaluate and reward professional activity in the context of each institution's special mission and objectives. Evaluation must recognize the varied purposes of research and professional activity. Some research — the minority — benefits mathematics directly by advancing the frontiers of knowledge. Most research and professional activity benefits mathematics indirectly by invigorating the faculty, stimulating students, and refreshing the curriculum. Both are necessary for mathematics to thrive, and both must be recognized and suitably rewarded.

An Agenda for Renewal

Successful undergraduate mathematics requires a faculty that is active, scholarly, and vigorous. To revitalize undergraduate mathematics we must infuse the undergraduate years with the spirit if not the details of contemporary mathematical activity. We must support exemplary programs that encourage students to major in mathematics. We must encourage creativity in developing programs for prospective school teachers as well as for prospective scientists. We must reward those who provide effective courses in "mathematical literacy" for future lawyers, politicians, and citizens. And perhaps most important, we must establish standards for faculty evaluation that promote innovation in teaching and scholarship in mathematics.

To be specific, an agenda for renewal should include such things as:

- Undergraduate scholarly activities, to provide for mathematics students what the laboratory does for science students and the stage for drama students.
- Curriculum modernization, to bring into the undergraduate curriculum the most exciting ideas of modern applied mathematics.
- Interdisciplinary efforts, to show how mathematical ideas can illuminate many of the broad issues — energy policy, economic theory, strategic doctrine — that capture the imagination of undergraduate students.
- Redefinition of the core of undergraduate mathematics, to determine what subjects all mathematics majors should know.
- Recognition of scholarship rather than narrow research as the true mark of professional activity for college mathematics teachers.

For the rest of this decade mathematics departments will continue under great stress. We live in the shadow of computer science, the glamor stock of academia. In contrast to computing, mathematics appears as a cerebral abstraction, isolated from reality.

Industry is hiring mathematics graduates as never before; society is pressuring the schools to stress mathematics; and the scientific research community has endorsed mathematics as one of the priority areas for support in years ahead. It is important that we not let these opportunities slip away.

Teachers of undergraduate mathematics must make every effort to convey not only to our students but also to our colleagues and to the general public the contributions mathematics is making to society. The great lesson of the past twenty years is that the most abstract ideas are the most powerful, and the most abstract thinkers the most versatile.

Testimony on Undergraduate Mathematics

presented to

The Committee on Undergraduate Education

of the

National Science Board

November 20, 1985

by Lynn Arthur Steen, President
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Mr. Chairman, Members of the Committee, and Guests:

I am very pleased that the National Science Board has undertaken a study of undergraduate education. As President of the Mathematical Association of America (MAA), I am especially pleased to have been invited to testify about collegiate mathematics. Most of our 20,000 members teach college mathematics, and most of the undergraduate mathematics education in this nation is provided by members of our Association. I speak also as a member of the Council of Scientific Society Presidents (CSSP) in commending you for this study, especially since last spring CSSP adopted unanimously a resolution urging continuing NSF support for both collegiate and pre-collegiate programs in science and engineering education [1]. We applaud your interest in collegiate mathematics and in its relation to science and engineering education.

I am Professor of Mathematics at St. Olaf College in Northfield, Minnesota, one of the science-intensive liberal arts colleges referred to by Frederick Starr in his earlier testimony to this Committee. St. Olaf has 3,000 students; about 10% of each year's graduates major in mathematics. The quality of our program, and of those at many of the leading liberal arts colleges, was strengthened during the last decade by many former collegiate programs of the National Science Foundation: Undergraduate Research Participation, Instructional Scientific Equipment, Science Faculty Fellowships, Comprehensive Aid to Undergraduate Science Education.

These NSF programs accomplished good things in their time, and I can say from first-hand experience that they helped enormously to strengthen the mathematics and science programs at my institution. Today, however, I am going to speak not particularly about these programs or about liberal arts colleges, but about the needs of collegiate mathematics across the nation.

Mathematics

As I'm sure you know, mathematics is both an enabling force and a critical filter for careers in science and engineering. Without quality education in mathematics, we cannot build strong programs in science and engineering. NSF policy for science and engineering education--both precollegiate and collegiate--must be built on this central fact: Mathematics is not just one of the sciences, but is the foundation for science and engineering.

The relations between mathematics and science have always been close. But because computers make possible mathematical analysis of many scientific and engineering processes, these relations are now both more pervasive and more significant than ever before. Whereas in the past only theoretical science required advanced mathematics, today all science-based fields use sophisticated mathematical models. This suggests another fact that dominates the undergraduate curriculum: Mathematics is changing dramatically in content, in scope, and in application; it is not only being applied, but is being continually created.

Several recent studies [2, 3] call attention to sudden growth in the frontiers of the applied mathematical sciences, a growth which is creating unprecedented demand for individuals capable of creating and using mathematically-based scientific tools. These studies point to such things as communication theory, transonic flow, chemical reactions, computational complexity, quantum field theory, computational statistics, combinatorial optimization, pattern recognition, ill-posed problems, non-linear equations, and parallel computing.

This growth in mathematics and its applications forces fundamental rethinking of the mathematics curriculum. Yet because mathematics education is a continuous sequential process from primary school through graduate school, changes in any part have important consequences both for other parts of mathematics education and for subsequent courses in science and engineering. The results of advanced research influence the curriculum at every level, while at the same time mathematics education lays the foundation for research of the future. These close links between education and research have stimulated promising new alliances in the national mathematics community [4], alliances based on a shared belief that mathematics, from education through research, is a seamless fabric.

Collegiate Mathematics

Collegiate mathematics stands at the interface of educational and research issues in the mathematical sciences. The mathematics faculties of our colleges must provide courses for future scientists and engineers, programs for prospective elementary and secondary school teachers, strong majors for those intending to enter graduate school, remedial courses for those entering college unprepared in mathematics, general education courses for students not majoring in a scientific discipline, and a variety of service courses ranging from elementary statistics to advanced operations research. Moreover, in most institutions mathematicians also teach some computer programming and elementary computer science.

The future quality of our nation's science and technology depends on the ability of today's mathematics faculties to meet these diverse obligations. Exciting developments in the mathematical sciences resonate with creative ideas for curriculum innovation to provide challenging opportunities in undergraduate mathematics. Yet the record of the recent past suggests that our mathematics faculties are under great stress, and are increasingly unable to meet national needs in collegiate mathematics [5].

For example, demand for undergraduate mathematics courses has doubled since 1970, but during that same period the nation's college mathematics faculty has increased by only about 50%. Each term about three million students receive mathematics instruction from about 30,000 faculty members. Despite this record demand for mathematics courses, the number of students majoring in mathematics has declined by over 50% and advanced (post-calculus) enrollments have declined from 20% to 5% of undergraduate mathematics. Indeed, approximately three quarters of all mathematics credits awarded by colleges and universities are for courses more appropriate to the secondary school curriculum. What's worse, about 100,000 workbooks are sold each year on the subject "Arithmetic for College Students."

Remedial, elementary and service courses drain faculty time and energy. Increased elementary enrollments combined with decreasing numbers of majors have simultaneously unbalanced the curriculum and depressed faculty morale, energy, and aspirations. In too many departments, the result is a downward spiral of withdrawn faculty, uninspired teaching, and uninterested students.

Other signs of stress are harder to quantify, but no less real. Mathematics departments, with few exceptions, do not have adequate access to computing resources that are appropriate to the actual use of mathematics in today's scientific and industrial world. As a consequence, computing has had very little impact on the mathematics curriculum--neither on what should be taught nor on how it is taught. In this age, undergraduate mathematics needs to be conducted in active symbiosis with powerful computers--for symbolic manipulation, for graphical display, for numerical analysis, and for simulation.

Computers are important tools for scientific and engineering modelling precisely because they enable effective applications of mathematics. As an engine for applied mathematics, a computer embodies powerful approximate techniques that have greatly expanded the scope of mathematical models: what formerly existed only in theory now occurs every day in every laboratory right before our eyes. The computer revolution is just the visible tip of a much deeper revolution in applied mathematics.

Inevitably, the availability of computers and the demand for new applications compels us to rethink priorities for mathematics education at all levels. To prepare students adequately for their careers in the twenty-first century, undergraduate mathematics programs must include core principles of computer science (algorithms, data structures, complexity theory); a contemporary view of numerical methods and approximation techniques; robust, computer-intensive statistical methods; graphical techniques for exploratory data analysis; and computer algorithms for optimization problems. This constellation of subjects is now widely known by the title "mathematical sciences," although the word "mathematics" is still often used as a short-hand synonym [6]. The reality behind the name is both simple and awesome: undergraduate mathematics is a totally different subject than it was twenty years ago.

Unfortunately, in far too many departments, mathematics courses are dated both in spirit and in content--primarily because faculty have not had sufficient opportunity for professional development. An active college mathematics curriculum should change half its courses every decade. For example, courses in mathematical logic, discrete mathematics, operations research, theory of computation, and combinatorics, although rare ten years ago, are now commonly offered by every good department of mathematical sciences. Creating these courses --and their successors for the next decade--is an essential but too often neglected part of the work of college faculties.

Liberal Education

Equally demanding and even more neglected are the challenges of providing mathematical courses appropriate for liberal education [7]. For students in the arts and humanities, mathematics is an invisible culture--feared, avoided, and consequently misunderstood. Too often such students are forced to retake high school courses whose only purpose is to master skills that now can be performed far better by a computer. Illiteracy in mathematics breeds illiteracy in science and technology, thereby driving the two cultures even further apart.

In a society dominated by complex systems we need to do far more than we now do to convey to our society's future leaders--our present students--that mathematics is not magic, and that even those without advanced technical training need to know how to ask appropriate questions and demand responsible answers [8]. We live in a "minds-on" world created by tools of applied mathematics--robotic devices, economic models, war games, expert systems--yet plagued by ethical issues of hidden assumptions and unintended side effects. In some systems order begets disorder, while in others the reverse is true. Paradoxes, dilemmas, and uncertainty pervade complex systems, whether in biology or in economics, in engineering or in medicine. As computers begin to dominate the areas of certainty--calculations--we must cultivate in humans--our students--a tolerance of ambiguity and understanding of uncertainties that abound in the scientific and mathematical models of our daily lives. This is yet another important task for an already overworked faculty.

Mathematics in the Marketplace

In the 1970s the tight job market drove many students away from careers in mathematics teaching; now attractive offers from industry and computer science are doing the same. As a consequence, the age distribution of the mathematics faculty is heavily skewed towards the upper end: over three-quarters of the nation's mathematics faculty was educated in a pre-computer age. Despite the increasing demand for collegiate mathematics, too few new Ph.D.s are in the pipeline for replacement positions. The number of new U.S. citizen doctorates available for replacement in college and university mathematics departments is now as low as in the pre-Sputnik era (under 400 last year), and one third of those enter industry. Over 40% of the Ph.D.s, and in some departments over two-thirds of the graduate students are from other countries [9]. Once again, as happened for different reasons a generation ago, U.S. mathematics is becoming a subculture of immigrants.

At the bachelor's and master's level, the demand for mathematics graduates has never been greater. We all know of the serious national shortage of graduates who are adequately prepared to teach high school mathematics. What may not be so evident is the dramatic increase in demand from industry for students with bachelor's or master's degrees in the mathematical sciences to join teams dealing with computing, statistical or management issues. The academic focus of these "mental" or "artificial" sciences (as distinct from the "natural" sciences) resonates with the needs of industry for employees trained to work with abstract, quantitative, symbolic models. Salary data, an indirect indicator of demand, supports the anecdotal evidence from many departments that demand for such individuals is very high.

Totally apart from education, the manpower needs of industry and defense are truly staggering. Supercomputer installations alone, estimated to reach about 200 per year by the early 1990s, will each require a dozen or so scientists capable of understanding and advancing research in scientific computing. Although these scientists will in many cases have advanced degrees in science, computer science, or engineering, all would need at least the equivalent of a good undergraduate major in mathematics.

To put all this in perspective, you should know that each year the United States produces only about 10,000 bachelor's degree graduates in mathematics, only 10% of whom go on to a Ph.D. in any field. Just to support the needs of scientific computing, to say nothing of the needs of high school and college teaching, the United States will need to double the number of undergraduate mathematics majors. And as we all know, the total population of college-age students will continue to decline for another ten years.

However, increasing the number of undergraduate majors in the mathematical sciences is not in itself a sufficient response to our manpower needs. It will not help at all to just cut lower in the talent pool for undergraduate majors. What we need, instead, is a nation-wide endeavor to attract the best young minds to undergraduate mathematics, not just to replenish the Ph.D. pipeline in mathematics, but to support all fields of science and engineering that build on solid training in undergraduate mathematics. I submit that the only effective way to do this is to make sure that across the country, in every college, large or small, there are mathematics teachers who are professionally alive, involved in their field, knowledgeable about recent advances in applicable mathematics, and conversant with the many challenging problems yet to be solved.

Strategies for Renewal

In summary, our nation faces serious challenges in undergraduate mathematics, ripe with opportunities for both professional and liberal education. Yet our mathematics faculties have to a large extent been left behind by the dramatic impact of computing and are cut off by lack of time for professional development from the rapidly advancing frontiers of their own discipline. As a consequence, they preside over a curriculum dominated by courses that are either too elementary or too old-fashioned. Although this portrait is not typical of the research universities and selective liberal arts colleges, it is, I believe, a fair assessment of collegiate mathematics at most of the nation's two- and four-year institutions where the vast majority of our students are educated.

Revitalization of undergraduate mathematics will require programs in colleges across the country that are closely linked to the frontiers of pure and applied mathematics. Students in every institution--not just at Berkeley or Harvard, St. Olaf or Swarthmore--need to see mathematics as an active, growing discipline with challenging unsolved problems worthy of their serious attention. This applies to future scientists and engineers as well as to future mathematicians; it applies as well to future lawyers and doctors, educators and ministers. Educated people need to know that mathematics is active, and that its applications really matter.

For all the reasons that have traditionally rooted good teaching in sound scholarship and research, it is essential that undergraduate faculty maintain active professional lives. To be realistic we have to recognize that only a select few will truly advance the research frontiers of mathematics--and be eligible for support by traditional research grants from NSF and other agencies. Recent studies suggest that about 10% of full-time college mathematics faculty members are actively engaged in publishable, competitive, first-class research. For the vast majority, mathematical scholarship is more necessary and more appropriate as a stimulus to thinking, an inspiration for teaching, an example to attract students into careers in mathematics, and a means of incorporating recent developments into the undergraduate curriculum.

Research in mathematics is not like research in the laboratory sciences. Whereas undergraduate research can thrive in most chemistry, biology, or physics research laboratories, research in mathematics is so far removed from the undergraduate curriculum that little if any immediate benefit to the undergraduate program ever trickles down from standard NSF research grants. Publication patterns provide vivid proof: hardly every does one see papers in mathematics jointly authored with students, either graduate or undergraduate. There are a few exceptions--in applied mathematics, in statistics, and in new areas of combinatorial mathematics. But as a general rule, undergraduates can neither participate in nor even understand the research activity of their mathematics professors. Programs to support collegiate mathematics must recognize this basic difference.

The key to revitalization of collegiate mathematics is a faculty that is intellectually alive. For some, that means research; for others, problem solving. Still others may engage in curriculum reform, lateral growth into new disciplines, introduction of computer methods, or development of teacher training institutes. What matters most is that the faculty develop an environment in which students can encounter mathematics as a living, growing discipline.

Need for Action by NSF

Collegiate mathematics requires support by the National Science Foundation for two simple reasons. First, mathematics is a critical national resource that is no longer being renewed at a rate adequate to meet the future needs of our nation. Second, without active support from NSF the necessary renewal probably will not occur.

Others in these hearings have argued that the crucial needs of science and engineering education are support for faculty, facilities, and instrumentation. For collegiate mathematics, I would put it differently: our need is support for faculty, faculty, and faculty. Nothing is more important to college education than a faculty that is intellectually alive: no amount of bricks, mortar, or silicon can substitute for lack of faculty energy, imagination, or will.

A rapidly advancing discipline together with steadily increasing teaching loads leaves most faculty with no time for necessary professional development. But lack of time is not the only issue; so is lack of compelling professional incentive. Continued NSF emphasis on research grants reinforces the natural tendency of deans and tenure committees to emphasize traditional published research above almost all else as a measure of individual worth in the academic world. If we want to improve undergraduate education, we have to readjust the academic reward system to provide a better balance between research and professional development.

Research for its own sake leads directly to fundamental advances in knowledge. What I am talking about is scholarship in the service of education, a bridge between the two fundamental missions of our educational system which leads indirectly to research in the future. In mathematics especially, we need NSF programs that build these bridges.

Suggestions for Action

First, I'd suggest a competitive system of NSF Faculty Fellowships, sufficient in number to invite large numbers of applicants and sufficiently varied in purpose to promote a wide variety of accomplishment: curriculum development, student projects, professional travel, research support, computer needs. Such Fellowships should be specifically targeted for projects that seek the improvement of undergraduate education; they would make a major impact on professional development of the collegiate mathematics faculty across the nation.

The act of applying by itself is a good first step in developing a sound program of professional development; in many cases local funds might be found even if the application is unsuccessful. Fixed stipends would favor those who most need the support--younger faculty in smaller institutions. By standardizing the financial award and by streamlining the selection process (perhaps by subcontract to professional societies), the Foundation could support sufficiently many individuals to attract many faculty to apply. Ideally, there should be many awards even in departments where there may not have been any similar grants in recent memory--and where the leverage of these Fellowships would be the greatest.

Here's another way to make an immediate dramatic impact on the ability of the nation's mathematics faculty to offer a challenging, modern curriculum: Put a high-powered computer work station on the desk of every college and university mathematics instructor. College mathematicians know enough to teach themselves how to use it, and ever afterwards they will teach their students in a different and more effective way. I do not propose this as an equipment program, but as an innovative means of making an immediate and much-needed impact on faculty development. In the long run, computers should be supported by institutions, as desks and typewriters now are. But in one bold move, without elaborate review procedures or continuing commitments, the Foundation could transform the teaching potential of the entire mathematics faculty of this nation.

Third, to increase leverage of limited NSF resources, and to reach the many faculty who never deal with government agencies, it would be wise to take advantage of the expertise of existing professional organizations (NCTM, MAA, AMS, CBMS, MSEB, BOMS, etc.) that already have in place effective national networks of meetings, publications, and professional support activities. The present undergraduate mathematics major, common to almost all institutions, was the result of an NSF-supported effort in the post-Sputnik era to use the leverage of professional societies in laying out guidelines for a modern curriculum. We need to take similar action now to engage teachers across the country in a way that provides great benefit for least cost.

Finally, to make any of these suggestions operationally effective, the Foundation must recognize that mathematics is different from science, and that undergraduate education is different from research. The relation between research and teaching in mathematics is not the same as it is in science; the role of mathematics as a foundation for science and engineering is unique; and the sheer magnitude of mathematics education (pre-college and collegiate) sets it apart as distinctive. For these reasons, it is essential that the Foundation solicit continued advice from individuals with substantial experience in undergraduate mathematics. Research expertise is no guarantee of good judgment in collegiate issues, nor is experience in laboratory science a good guide for the needs of the mathematical sciences. Thus my fourth and most urgent recommendation: Make sure that NSF proposal reviewers, members of advisory committees, and staff members are selected so as to provide balanced, informed advice, including appropriate numbers of individuals with substantial experience in undergraduate mathematics.

Conclusion

The mathematics community itself has recognized the need for coordinated action to address the basic facts of mathematics and mathematics education: that mathematics is fundamental to science, that it is changing rapidly, and that it is a seamless fabric from grade school to graduate school. Unfortunately, the traditional separation of education from research continues in foundation funding practices as it does in university tenure and promotion proceedings. This division is both an anachronism and an impediment at a time when the mathematical organizations themselves are working hard to bridge the gap between research and education in the mathematical sciences. The greatest contribution NSF could make to undergraduate mathematics would be to help us close this gap.

Notes

[1] On May 15, 1985, the Council of Scientific Society Presidents unanimously adopted the following resolution: "Mathematics, science and technology education are essential to the long range security and economic well-being of the nation. Therefore, the Council of Scientific Society Presidents commends those members of the Administration and Congress who have supported urgently needed funding for the National Science Foundation education budget. In particular, to provide needed long-term leadership, we strongly urge support for a continuing annual baseline National Science Foundation budget of at least 100 million dollars for college and pre-college science and engineering education."

[2] The changing nature of mathematics and its relations to science and engineering are described very well in the 1984 report "Renewing U.S. Mathemetics" prepared by a committee of the National Research Council chaired by Edward E. David, Jr. Arthur Jaffe's paper "Ordering the Universe: The Role of Mathematics" in Appendix C outlines major recent contributions of mathematics to problems of computation, physics, engineering, and communication.

[3] Extensive discussion of the needs in scientific computing are contained in the recent report "Future Directions in Computational Mathematics, Algorithms, and Scientific Software" of a panel chaired by Werner Rheinboldt (see *Notices of the American Mathematical Society*, November, 1985).

[4] The impact of the David Committee's report together with parallel work by the Conference Board of Mathematical Sciences (CBMS) set the stage for the National Research Council to establish two Boards--the Board on Mathematical Sciences (BOMS), and the Mathematical Sciences Education Board (MSEB)--to provide a continuing national capability to assess issues in mathematics research and mathematics education. Through these Boards the nation has an unprecedented opportunity for coordinated leadership in mathematics and mathematics education.

[5] The state of collegiate mathematics is described more fully in my paper "Renewing Undergraduate Mathematics" which appeared in the August 1985 issue of the *Notices of the American Mathematical Society*.

[6] The definition of an undergraduate major in the mathematical sciences was set forth formally for the first time in a 1981 report of the Committee on the Undergraduate Program in Mathematics (CUPM): "Recommendations for a General Mathematical Sciences Program," Alan Tucker (Ed.),

Mathematical. Association of America, 1981. Similar issues are discussed in the papers in two more recent volumes, each based on conferences sponsored by the Alfred P. Sloan Foundation: The Future of College Mathematics, Anthony Ralston and Gail Young (Eds.), Springer-Verlag, 1983, and New Directions in Two Year College Mathematics, Donald J. Albers, Stephen B. Rodi, and Ann E. Watkins (Eds.), Springer-Verlag, 1985.

[7] For fuller discussion of current issues in liberal education see "Integrity in the College Classroom," a recent report of the Association of American Colleges that attributes the devaluation of undergraduate education to a conflict between narrow graduate-school professionalism and the broader goals of liberal education.

[8] See my paper "Mathematics: Our Invisible Culture", prepared for the September 1985 Tome Centennial Symposium on Science and the Liberal Arts at Dickinson College.

[9] An article in the 15 November 1985 issue of Science ("Americans Scarce in Math Grad Schools", p. 787) cites examples of top-ranked graduate programs in mathematics in which only one-fourth of entering graduate students are U.S. citizens. This information suggests that the downward trend in percentages of U. S. citizens among mathematics Ph.D. degrees will continue for quite a few years.

Collegiate Mathematics in the Year 2000: Assessment for Renewal

A Proposal to the

Board on Mathematical Sciences
and the
Mathematical Sciences Education Board
of the
National Research Council

Prepared by the

Planning Committee for a National Study of Resources for Collegiate Mathematics

February, 1988

The Planning Committee for a National Study of Resources for Collegiate Mathematics was appointed by the Mathematical Association of America and charged with the preparation of this proposal. The charge to the Committee was endorsed in a resolution by the Joint Policy Board for Mathematics (American Mathematical Society, Mathematical Association of America, and Society for Industrial and Applied Mathematics). Members of the Planning Committee are Wendell H. Fleming (Brown University), Ettore F. Infante (University of Minnesota), Bernard L. Madison (University of Arkansas), Stephen B. Maurer (Swarthmore College), and Hugo Rossi (University of Utah). Kenneth M. Hoffman (Massachusetts Institute of Technology) and Lynn A. Steen (St. Olaf College) serve as ex-officio members. Marcia Sward, Executive Director of the Mathematical Sciences Education Board, served as an ex-officio member while Associate Director of the Mathematical Association of America. The Committee was chaired by Professor Madison.

The Planning Committee gratefully acknowledges that its work was supported by a grant from the Alfred P. Sloan Foundation.

Collegiate Mathematics in the Year 2000: Assessment for Renewal

Collegiate mathematics is a critical national resource, increasingly vital to science, engineering, technology, and society in general. Each term more than three million students receive mathematics instruction from about 30,000 faculty members at more than 2500 postsecondary educational institutions.

The responsibilities of collegiate mathematics include instruction of:

- students in academic areas that use mathematics;
- mathematics majors;
- pre-college teachers; and
- the general population for quantitative literacy.

Because of the profound effects and enormous potential of this educational mission, improved quality in all these areas must become a national goal supported by a firm commitment from the mathematical sciences community.

Events of the past fifteen years have broadened considerably the responsibilities of collegiate mathematics, and the next fifteen years promise further changes, new opportunities, and serious problems. Although U. S. mathematics is still strong, many danger signals are now visible. To meet present challenges and seize current opportunities, corrective measures are urgently needed. Traditional uses of available resources for collegiate mathematics departments will prove insufficient to provide the U. S. with an adequate supply of mathematically trained graduates.

During the period 1970-1985 the demand for mathematics instruction in U. S. colleges increased sharply in both scope and magnitude. Business curricula as well as those in the social and biological sciences became more quantitative. The spectacular growth in the computer industry brought significant changes in the kinds of mathematics needed by science and engineering majors and created the need for new instruction for computer and computation specialists. Curricula appropriate for students who will teach and work during the next century differ significantly from those devised during the 1960s. It is important that we educate both for our best estimates of the future and for enhancing the abilities of our graduates to welcome and adapt to change.

Ideally, faculty actions should have been the source of planning and study to meet these new challenges. However, the collegiate mathematics faculty has been too limited in time, training, and volition. Faculty replacements have been few in recent years and retirements will increase, insuring that substantial numbers of new collegiate mathematics faculty will be needed by the year 2000. However, the source for people for this renewal of the faculty is doubtful because the number of students majoring in mathematics is now rather low. A central and urgent problem is maintaining a steady flow of mathematical talent.

In view of this situation, with increasing national focus on undergraduate education and mounting concern in the mathematical community, it is a propitious time -- and fortunately not too late -- to conduct an assessment of the status of collegiate mathematics, to set goals for the year 2000, and to determine the resources required to meet these goals.

We propose here a study of the status of collegiate mathematics in order to provide a framework for renewal by the year 2000. Such a study would include:

- analysis of data to provide a national assessment of needs, resources, and opportunities in collegiate mathematics;
- articulation of standards for curricula, faculty, resources, quality, and productivity of college mathematics departments;
- recommendations for action by various organizations responsible for higher education -- colleges and universities, Federal agencies, state governments, foundations, professional societies, and college faculty.

Quality collegiate mathematics is important for all academic disciplines and, indeed, for all of society. Most college curricula require mathematics -- many a substantial amount. The early study of mathematics allows a student flexibility later in choosing a major area, while the absence of such study sharply limits major options. The problems faced in collegiate mathematics instruction are unique and very difficult. In no other discipline do students display such diverse abilities and levels of knowledge, yet success in mathematics is usually a prerequisite for later study. The fundamental role played by mathematics in ordering the world in which we live gives this proposed assessment of collegiate mathematics a broad national significance. It is important that the study be addressed at a national level with a greater perspective and detachment than could be achieved by any single professional society.

Background

National concern for the quality of education has produced numerous reports in the past three years, led by *A Nation at Risk*. Within just the past year at least four independent national reports have reached remarkably similar conclusions about the state of undergraduate education -- one of incoherence, confusion, aimlessness, and lack of rigor [1,2,3,4]. Some of these general problems affect college mathematics, adding to the special burdens mentioned above. As a national staple of undergraduate education, mathematics is a logical choice as a point discipline for assessment and rejuvenation of collegiate education.

Although there has never been a comprehensive study of the status of collegiate mathematics, there are numerous sources of data and collateral analyses. The National Research Council's 1984 report *Renewing U. S. Mathematics: Critical Resource for the Future* (the "David Report"), summarized in [5], outlines an agenda to restore support for research mathematics to parity with other disciplines. The Conference Board of Mathematical Sciences (CBMS) has conducted undergraduate surveys every five years since 1965 (see [12]), and the American Mathematical Society (AMS) annually surveys departments for information about faculty demographics, salaries, and enrollments (see [10, 11]). Curricular studies have been carried out for over two decades by the Committee on the Undergraduate Program in Mathematics (CUPM) of the Mathematical Association of America (MAA). Within the past year several analyses of the trends suggested by this data have appeared (see [5,6,7,8,9]), but there has been no systematic attempt to project needs or resources for the years ahead.

Collegiate mathematics in the U. S. is an extensive enterprise affecting a significant fraction of the population each year. To understand this enterprise requires knowledge of:

- student preparation and interests;
- faculty background and abilities;
- mathematics requirements of other disciplines;
- standards and content of academic programs;
- resources available to mathematics departments;
- public perception of the mathematical sciences;
- self-perception of the mathematics faculty and students; and, very importantly,
- the role of mathematics today and its likely role tomorrow.

A major outcome of this study will be the mirroring of collegiate mathematics for faculty members to give them better understanding of the critical issues and how they should be addressed.

Rationale

The rationale for the proposed study can be summarized in three major points:

I. The mathematical sciences are changing rapidly, creating great potential for new initiatives. However, many college mathematics teachers are either unaware of the consequences these changes should have in the curriculum, or are unable to respond because of inappropriate education or lack of necessary resources.

II. No strong incentives exist for attracting students and faculty into the mathematical sciences, for keeping faculty active in scholarly pursuits, and for promotion of excellence in teaching.

III. The vitality of the nation's science and engineering is inextricably linked to the health of collegiate mathematics.

Changes are occurring both within collegiate mathematics and in areas that directly affect it. Within mathematics, fundamental research has progressed with astounding speed, depth, and generality, exciting new applications of mathematics have been found, and there has been a merging of interests within the mathematical sciences as well as between it and other areas of science and engineering.

Enrollment patterns and numbers have changed dramatically. Teaching loads have increased, salaries have decreased in real terms, and about two-thirds of the collegiate mathematics faculty are not considered productive scholars within the scope of the traditional and current definition of research in mathematics. Other changes affecting mathematics include the altering of standards in pre-college and college education, the new pervasiveness of the computer, and the maturing of computer science as a separate academic discipline.

The second major point (II above) underlies the central problem of maintaining a steady flow of mathematical talent. Student enrollments in mathematical science degree programs have decreased significantly at all levels. The current number of Ph.D. degrees awarded annually is not sufficient to meet the present demands, and, as we near the year 2000, the shortage will become much worse unless changes occur. The percentage of foreign nationals among graduate students and new Ph.D. recipients is nearing one-half of the total population. The increases in the use of part-time faculty members and the decrease in the percentage of faculty holding a doctorate degree have been unwelcome consequences of these conditions. The number of bachelor's degrees both in mathematics and in mathematics education has dropped significantly in recent years. Unattractive working conditions for academic mathematical scientists and higher salaries in industry have both contributed to the reduced numbers of collegiate mathematicians. Considering the long lead times and other factors involved, the collegiate faculty and other groups needing mathematical scientists are facing real trouble by the year 2000 if good young people are not attracted into the field soon.

The third major point (**III** above), the dependence of the nation's science and engineering on the health of collegiate mathematics, is an established fact. It provides as a compelling reason for this study the increased need for mathematical resources in science and engineering. The David Report has detailed the state of mathematical sciences research, the support for such research, the consequences for continuing on the present path, and an agenda for renewal. In 1985, the National Research Council issued the report *Engineering Education and Practice in the United States: Foundations of our Techno-Economic Future*, detailing the case for support of engineering. Accrediation of computer science programs has begun. These and exciting developments and expansions in other sciences increase the pressure on collegiate mathematics, both in the competition for limited resources and in the challenge of providing quality mathematics instruction as a foundation for new areas of science and engineering.

Proposal

We propose a national study of collegiate mathematics with three components: analysis of data, articulation of standards, and recommendations for action.

Analysis of Data. We must understand the present situation and draw implications from current data for the future. Information on faculty, students, enrollments, achievements, and perceptions should be identified, analysed, and where missing, gathered.

Population projections should be examined, as should information on anticipated needs in the labor force. All data on the renewal and replacement of the collegiate mathematics faculty as well as the role of collegiate mathematics in the supply of pre-college teachers should be understood in the context of society's needs for mathematical training. Current student enrollments, projections, and implications must be known.

The state of the curricula in mathematics requires assessment relative both to current needs and needs estimated for the year 2000. The roles of academic degrees in mathematics and their relationship to general education and societal development should be articulated and studied. Destinations of mathematics majors -- one, two, or more years after graduation -- should be studied and related to training and curricula.

The education of the mathematics faculty should be analysed relative to the expectations from and responsibilities of this group. Their scholarly production and their teaching effectiveness should be assessed, especially in the broader areas of instruction now needed in applied areas of the mathematical sciences. The demands on this faculty by the year 2000 should be projected, identifying what enhancements are necessary to meet those demands.

Expectations from several sources for collegiate mathematics influence its roles and effectiveness -- expectations from within the mathematical community, from those directly served by collegiate mathematics, and from the general public. Those expectations need to be articulated and compared with reality so that the directions and goals of mathematics can be well understood. Of particular importance are the expectations of mathematics by other collegiate disciplines, especially those closely aligned to and dependent on mathematics.

The sufficiency of resources available to collegiate mathematics needs to be assessed. These resources include personnel, physical facilities, libraries, computing machinery, and opportunities for professional development and teaching excellence. In addition to an assessment of available resources, the efficiency and effectiveness of the ways resources are currently used need to be evaluated.

There are considerable data available on faculty salaries and demographics, course and program enrollments of students, and recommendations for curricular content. Data on structure of actual curricula scholarly production of the faculty, and institutional support of departments have not been systematically gathered. The extent of changes in and their effect on departments, articulation of the problems they face, and the various perceptions of college mathematics are currently understood only through anecdotal information.

Articulation of Standards. We must spell out reasonable national targets for the year 2000 concerning various aspects of collegiate mathematics: curriculum requirements, faculty preparation, student achievement, resources for research and professional development, and teaching excellence. Such targets must be challenging yet realistic, rooted in the aspirations of American science and industry as they enter the 21st century and the need for quantitative literacy in an increasingly complex society.

Among the curricular questions that need consideration are the following. What are the aims of and appropriate content for an undergraduate degree program in mathematics? What are proper standards of student achievement? How are challenging and effective service courses developed? What are appropriate levels for college mathematics, especially in relation to remedial courses, specialized service courses, and general education courses?

As both a part of and an extension of the study of the college mathematics curriculum, the transition from high school to college merits special attention. At the other end of collegiate education, the transition for mathematics majors from undergraduate school to either graduate school or employment needs study.

To articulate a setting for excellence in teaching, the following questions need answers. What is a proper environment for quality mathematics teaching, including intense student involvement? What is appropriate faculty preparation for this teaching and what concurrent faculty activities are necessary to keep teaching effective and intellectually honest? What is appropriate prerequisite education for students of college mathematics?

The issue of necessary resources divides into two questions. What resources are necessary for an appropriately educated faculty to teach appropriately educated and motivated students; and what additional resources are needed to deal with students who are poorly prepared and insufficiently motivated? What resources are necessary to attract quality students and faculty in the right numbers into mathematics?

Recommendations for Action. We must identify appropriate actions by the many constituencies of higher education – colleges and universities, faculties, professional societies, state governments, foundations, Federal agencies – that should be undertaken now in order to move collegiate mathematics in the direction of the goals established for the year 2000.

Actions concerning resource support will likely be primarily the charge of colleges, universities, and state governments, but specific areas may be the responsibility of foundations and Federal agencies. Actions concerning the content and delivery of the college mathematics courses are mostly the responsibility of the faculties; and that responsibility extends to actions to revitalize scholarship, teaching excellence, and spirit in collegiate mathematics. The mathematical science professional societies are the logical choice to maintain pressure and encouragement to achieve the goals of this study and to project those goals beyond the year 2000.

The committee that undertakes the study should include individuals with a broad knowledge of collegiate mathematics, research in the mathematical sciences, and applications of mathematics to other disciplines. The issues overlap with the concerns of pre-college mathematics education and those of other collegiate disciplines. The study committee should have representatives from the mathematical sciences, mathematics education, academic users of mathematics, business and industry, administrators and trustees of higher education, and the public. Because of the interdependence and overlapping of issues, the scope of the study should include all aspects of collegiate mathematics, interpreted in the broader sense of mathematical sciences, including applied mathematics, computational mathematics, statistics, and operations research. The broad interest in and importance of collegiate mathematics across much of society make it essential that this study be conducted in a national context with enough detachment to make honest, realistic, and reliable assessments of the needs of collegiate mathematics in the year 2000.

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STATEMENT OF

PETER M. FANNON

PRESIDENT

NATIONAL ASSOCIATION OF PUBLIC TELEVISION STATIONS

BEFORE THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY

OF THE

UNITED STATES HOUSE OF REPRESENTATIVES

ON

AUTHORIZATION FOR THE

NATIONAL SCIENCE FOUNDATION

MARCH 1, 1986

The National Association of Public Television Stations (NAPTS) is pleased to present testimony in support of the important educational programs funded by the National Science Foundation's Science and Engineering Education Directorate (NSF/SEE). Our membership, the nation's 318 public television stations, has utilized funds from NSF through the years directly or indirectly to present to the American public high quality science education programming. We have been grateful for this important federal support which has responded to the clear need for science education nationwide.

Over the last few years, the Congress and the American public have become increasingly alarmed over the appalling state of science and mathematics education at all levels from elementary to post-graduate. Our national shortage of qualified, interested math and science teachers has reached critical proportions. Higher levels of science education are not keeping up with the march of technology. Our educational system is not attracting enough members of the shrinking pool of college-age students to the engineering, math and science fields.

There is not any "quick fix" answer to these problems. There can be, however, an organized, concerted effort made by the nation's government to encourage the study of these vital fields by our nation's young people. Clearly there is an important role which can be played by public television.

We in public television have seen a tremendous response to the many science programs, some supported by NSF/SEE, that our stations produce and distribute. Science programs distributed by the Public Broadcasting Service (PBS) reach 18.5 million households--or 46 million viewers--in this country every week. Science programs represent three of the list of four most widely viewed programs on PBS, and taken as a group, science programming on public television geared at all age and education levels has larger audiences than public affairs and cultural and entertainment programming.

Our eight-part landmark series The Brain was carried by 275 stations covering 96 percent of the United States. Over 5.4 million households or 13.5 million people viewed at least one program. The success of The Brain, a series partially funded by NSF's Science and Engineering Education Directorate (SEE) was due in part to widespread public curiosity about the workings of the "incredible three pound machine" and in part to the wonderful adaptability of video technology to the complex subject matter.

This series produced by **WNET/New York** with the support of the CPB/Annenberg Project, NSF, the National Institute of Neurological and Communicative Disorders and Stroke, the National Institute of Mental Health, and the National Institute of Aging, has been adapted for use by two and four-year colleges and universities as a credited course, "Brain, Mind and Behavior." The series' overwhelming success has pointed very clearly to how the cooperative efforts of the federal government's science-related agencies and the public television system can combine to produce needed, academically oriented and well-received science programming.

The weekly science series NOVA produced by **WGBH/Boston**, received initial important NSF support in 1972 and was continually nurtured by NSF until our stations could afford to carry the programs' cost themselves. NOVA programs are seen by as many as 20 million Americans per broadcast and are the most highly used PBS programs as instructional television in our nation's schools. Nearly 95,000 high school teachers use the series to educate over 10.5 million students nationwide. NOVA has also been widely acclaimed by public officials and the media for presenting the scientific facts behind many domestic and international policy issues from acid rain to biological warfare to toxic waste.

To help educate our nation's students at the most critical point of their education, the elementary level, NSF/SEE wisely supported the development and production of our series produced by the **Children's Television Workshop** 3-2-1 Contact. Thanks to NSF/SEE, the first 65-program series is being repeated on public television, a new series of 40 programs was inaugurated in 1983, and a third series of 20 programs is now in distribution. 3-2-1 Contact is carried on 218 of our public television stations and is seen by 7.5 million viewers each week. Over 750,000 elementary school teachers receive the program's companion teacher guide, and science museums and schools have established weekend activities to support and extend the enthusiasm created by the program. The Children's Television Workshop is now in production on a mathematics series for this age group, also partly funded by NSF/SEE, along with the U.S. Department of Education.

We are all too well aware of our need to upgrade science teaching nationwide. From our perspective in public television, this situation is as unfortunate as it is unnecessary. The program production and distribution capabilities of this nation's educational television system offer a unique resource for the improvement of elementary and secondary science and mathematics education on a wide scale and in a cost-effective manner. Because our system reaches about 95% of the U.S. population, it is especially well-suited to reaching vast numbers of people as well as targeting specific pockets of students. Public television stations can develop and provide a comprehensive package of teacher-training materials--programs that can be used as in-service teacher training or as college-credit courses.

This kind of programming in cooperation with individual public television stations has been supported by NSF/SEE in the past. One series currently available for distribution to colleges and teachers was produced by the **New Jersey Network** with a grant from NSF/SEE. You, Me, and Technology aims to help viewers achieve technological literacy and an objective attitude toward technologies that searches for the trade-offs between their costs and benefits.

Public television also needs more college level courses, not just for our teachers, but for others in the workforce who need to upgrade their education. PBS's Adult Learning Service (ALS) is doing just that. By providing "telecourses"--college-level television series supplemented and reinforced with textbooks, study guides, and class meetings--PBS is reaching half a million college and university students at over 750 institutions of higher learning across the country.

As stated previously, the series The Brain is the basis for the television course Brain, Mind and Behavior currently offered by the ALS. A new physics course produced by the California Institute of Technology and the Southern California Consortium and offered by ALS this year, The Mechanical Universe, is attempting to provide three levels of physics instruction, one of them in cooperation with NSF. The Mechanical Universe can be geared either to liberal arts students fulfilling a general science requirement, to the science or engineering majors demanding more rigorous preparation, or to the secondary school teachers seeking to upgrade their physics teaching skills.

NSF has sponsored this last application by initiating a project in which parts of the course have been adapted for use in high school classrooms. Teachers who find themselves teaching high school physics in spite of inadequate preparation will find that by enrolling themselves in The Mechanical Universe course and using the NSF video modules in their classes, they will be able to present their students with instruction of the highest quality.

With the steady support of NSF through the years, public television has provided high quality science programming that equally fascinates and educates its intended audience. Our audience response has shown us that we need to develop more regular series like NOVA that explore new technology and scientific innovation and more limited series like The Brain that explore specific scientific fields. The tremendous success of 3-2-1 Contact and our college courses has shown that more efforts in those areas can help conquer "science fear" in our nation's student body.

The critical assistance and guidance provided by the National Science Foundation's Science and Engineering Education Directorate will continue to be necessary to achieving those goals. We urge you to authorize as much as you can for the work of the National Science Foundation and that NSF be encouraged to direct as much as they can to using our nationwide system of public television stations to help bring more science information and education to all Americans.

STATEMENT OF

THE ENGINEERING EDUCATION TASK FORCE of:

THE NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

THE NATIONAL ASSOCIATION OF STATE UNIVERSITIES
AND LAND-GRANT COLLEGES

on the

FY'87 National Science Foundation Authorization

before the
Subcommittee on Science, Research and Technology
Committee on Science and Technology
U.S. House of Representatives

February 25, 1986

Mr. Chairman and Members of the Subcommittee:

We appreciate this opportunity to share our views on the National Science Foundation authorization for FY'87. This statement is being submitted for the record by the Engineering Education Task Force, a multi-society task force convened in 1983 to bring together the resources of societies with mutual interests for the purpose of evaluating and developing legislative solutions to critical engineering education and research problems. The Task Force is chaired by Dr. Robert D. Kersten, P.E., Dean of Engineering at the University of Central Florida, who represents the National Society of Professional Engineers (NSPE). The other participating organizations are the American Society for Engineering Education (ASEE), including its Engineering Deans' Council, and the National Association of State Universities and Land-Grant Colleges (NASULGC).

NSPE is a non-technical professional society representing over 75,000 professional engineers of all disciplines nationwide, who are employed in industry, private practice, government, construction and education. ASEE represents over 10,000 engineers, primarily faculty, and over 250 accredited engineering schools, as well as more than 100 major engineering-oriented industries. Over 30% of all students enrolled in institutions of higher education attend the 144 NASULGC member colleges and universities, which include 24 of the nation's largest institutions and multi-campus systems of higher education.

In the current climate of intense fiscal austerity, we believe it is especially important to examine carefully all Federal expenditures in terms of their return on investment and the degree to which other sources of funding can be developed. From this perspective, the President's FY '87 budget request for the National Science Foundation clearly emerges as a vital insurance policy guarding our economic welfare and world leadership.

Unlike many areas of the budget, the National Science Foundation supports the development of resources that fuel economic growth. However, because the payoff from this investment in academic talent, training and research is only apparent in the long term, those unfamiliar with the Foundation's programs and accomplishments may not appreciate the critical role played by the NSF. Before looking at the specifics of the proposed budget, therefore, we would like to highlight this point.

It is often said that the National Science Foundation makes only a small contribution to the nation's research and technology base compared with the mission agencies. While it is true that other agencies fund a substantial amount of the nation's research, the largest share of that work is development, directed toward a specific commercial or military application. This type of support is focused on the final product, with the objective to advance the agency's primary mission. The next largest percentage of all federal R&D support is characterized as applied research, which again is geared toward a mission related result.

These forms of research support are not intended to advance the forefronts of knowledge, but to use the basic research results that already exist to benefit an agency's mission, such as defense. The smallest share of federal R&D expenditures is for basic research, which undergirds all other research and provides graduate students and faculty with opportunities to acquire sophisticated skills and knowledge. And the only agency in the federal structure responsible for advancing both people and research in this way is the National Science Foundation.

Again, though, an examination of the distribution of research funds by agency makes the NSF share of Federal funding of basic research, 16% under the proposed FY '87 budget, appear fairly insignificant. If only basic research performed at colleges and universities is considered, that share grows to 25%. In many areas, however, the unique role that the National Science Foundation plays is masked by these broad statistics.

This is especially true in engineering, where in several disciplines the NSF is almost solely responsible for both the research and talent addressing critical issues at the nation's colleges and universities. For example, in FY '84, the most recent year for which statistics are available, the NSF supported 74% of basic research in chemical engineering conducted at colleges and universities. In civil engineering, the figure rises to an astonishing 93%.

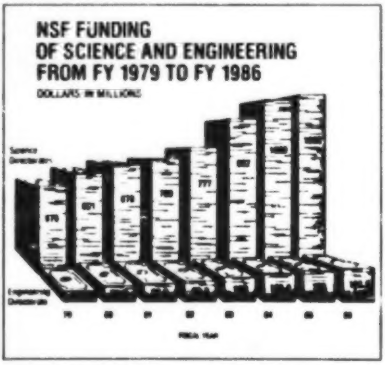
The reason why the NSF share is so high lies in the nature of the work, which is generic and therefore not of immediate interest to mission agencies or industry, but which has some potential for future application. For example, in the civil field, NSF is essentially the nation's only sponsor of fundamental engineering research in structural design, which generates more stress resistant methods for building bridges and other essential elements of the nation's public works infrastructure. This research is desperately needed; in past decades, and even today, these structures have been built using existing, though clearly outmoded, technologies. Without this most basic work, new methods will not come to fruition. And in many fields, particularly engineering, NSF funding serves to leverage non-federal resources, bringing the total investment in research and talent to a higher level than would otherwise be possible.

Clearly, the future growth of our nation depends on research in these and other critical engineering and scientific areas. With the National Science Foundation leading the way, advances in technology can help ensure a bright future.

Given that the National Science Foundation plays such a crucial and irreplaceable role in supporting the nation's academic foundation of research and talent in science and engineering, the need for stable funding becomes obvious. Neither research projects nor the researchers themselves can plan and perform high quality work without stable funding. To stop a research project midterm does not produce half of the expected results; it produces inconclusive, usually useless data. Rollercoaster funding for NSF does not just slow things down, it grinds the research and education enterprise to a halting stop, negating the valve of previous investments.

Therefore, while acknowledging that rapid growth of the NSF budget is not an option with the current fiscal crisis, we hope you and your colleagues throughout Congress will resist the temptation to reduce the proposed budget. The modest growth proposed allows advances in only the most pressing, promising areas such as biotechnology, the encouragement of more women and minorities to undertake science and engineering research and education challenges, and manufacturing processes. The budget request is both fiscally responsible and technologically exciting, no small feat considering the limitations imposed.

In engineering, the budget request is for $185.5 million, a 14% increase over the current plan for FY '86. Still, engineering accounts for only 14% of the total budget, a proportion that has not changed significantly over the last decade despite the growing importance of engineering to international technological competitiveness.



While this year is clearly not the time to suggest a massive investment of new funds into the engineering directorate, we do hope the Subcommittee will consider a long-term growth plan that will allow the Foundation to respond better to critical needs in engineering education and research. Last fall, the National Academy of Engineering performed an analysis of the NSF's engineering programs. The final report, New Directions for Engineering in the National Science Foundation, concluded that "The maintenance of this country's technological leadership cannot be assured in the absence of engineering research at the cutting edge of knowledge. Because the process of technological innovation depends directly upon the quality and quantity of engineering talent...it is vital that NSF regard this national challenge as a challenge to itself as an agency and, more specifically, to its engineering directorate."

The report recommends that to meet current needs, the budget of the engineering directorate should grow to between $350 million and $410 million per year. We strongly endorse the Academy's recommendation, and urge you to approve the proposed budget with this goal in mind.

The need for more resources does not stem from a desire to just conduct more research. Rather, the engineering education enterprise is desperately in need of rather substantial improvements. In trying to honor demands for good research and talented people, engineering schools find themselves struggling to maintain superior standards in the face of a variety of problems:

* **Engineering faculty shortages** remain of paramount concern. Currently, one in twelve budgeted positions is vacant. As many as 23% more positions are needed to bring the student-faculty ratio close to optimum teaching conditions.

* **High enrollments** at the undergraduate level strain an already sparse faculty and poor facilities. While enrollments have grown over 115% over the last fifteen years, faculty growth has been approximately 10%.

* **High quality** of entering students masks the poor "value added" being provided by undergraduate engineering education. The majority of entering freshmen are in the top 10% of their graduating high school class.

* **Unattractiveness of faculty careers** is furthered by limited incentives for bright students to pursue graduate engineering education. Fellowship awards should be increased to equal at least one half of starting B.S. salaries.

* **Deteriorating physical plants** detract from the quality of instruction and research, and reduce the attractiveness of an academic career.

The American Society for Engineering Education is nearing completion of a two year project, sponsored by thirty major corporations, to develop a strategy for ensuring the excellence of the faculty and the academic working environment in coming years. The four task forces of the Quality of Engineering Education Project (QEEP) have produced interim reports with tentative recommendations for schools, faculty, government and professional societies. A copy of those reports are attached for the record.

In sum, we urge you to support fully the FY '87 National Science Foundation budget request. The NSF plays a vital and irreplacable role in maintaining and enhancing the technological and economic strength of our nation.

QEEP

Quality of Engineering Education Project

Introduction

Project Director: W. E. Lear

Before the two-year Engineering College Faculty Shortage Project was completed in September 1983, the ASEE Board of Directors discussed the need to continue the project. Surveys undertaken in connection with the project had documented the seriousness of the problems facing engineering schools. Board members agreed that the lack of adequate numbers of qualified faculty was still a critical issue but that the continuing effort should be broadened to include all factors that affect the quality of engineering education. This program was labeled the Quality of Engineering Education Project (QEEP).

A committee appointed by then-President John Hancock developed a comprehensive proposal which outlined actions aimed at improving or restoring excellence in seven broad areas directly affecting the quality of engineering education. To seek advice on the proposed plan, the officers of the Society met in December 1983 with representatives of its industrial member companies and its government and association members. Convinced of the effort's merits but uncertain of how much could be tackled at once, the advisers suggested that since the faculty is the key to the quality of engineering programs, the project should concentrate on assuring the excellence of the faculty and the academic working environment in coming years.

"The project concentrates on assuring the excellence of the faculty and the academic working environment in coming years."

With this background, the QEEP Advisory Committee proposed a two-year program aimed at: 1) ensuring that U.S. engineering education has the faculty required for excellence in the decades ahead, and 2) addressing two critical issues in the future working environment of the faculty—the use of educational technology and the role of the undergraduate engineering laboratory. The project was formally launched on September 1, 1984, with support from 25 (now 28) corporations. Four task forces of eight to ten people each were organized, with membership drawn from industry and academia. These are

- The Task Force on Preparation for Teaching of Engineering,*
- The Task Force on Continuing Professional Development of the Faculty,
- The Task Force on the Use of Educational Technology, and
- The Task Force on the Undergraduate Engineering Laboratory.

The project has an Advisory Board composed of one member from each sponsoring company plus seven academic members appointed by the ASEE President. Directing the QEEP project is the Executive Director of ASEE.

In September 1985, at the end of the project's first year, each task force prepared for the Advisory Board a report of its efforts, including tentative findings and recommendations. The reports are preliminary and do not necessarily cover all topics that will eventually be addressed, nor at this point do they all represent complete agreement among members of a particular task force on the findings and recommendations.

The summaries that follow are presented to make known to ASEE members and others the directions being taken by each group. *Readers are urged to send (or phone) their suggestions and criticisms regarding any part of these tentative results to individual task force members, to the task force chairmen or to the project director.* The summary reports have also been presented at recent meetings of several ASEE sections, at the ABET annual meeting and at the Frontiers in Education meeting for discussion and criticism. Each task force hopes through this feedback process to receive advice it can use in developing a final report for publication in the fall of 1986.

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* The generic term "engineering" is intended to include engineering technology. Each task force addresses both engineering and engineering technology education.

QEEP
Quality of Engineering Education Project

Preparation for the Teaching of Engineering

Task Force Chairman: John D. Kemper

Charge: To examine the current modes of preparation of engineers for faculty positions, to determine the adequacy of that preparation for the present and future needs of the profession, and to recommend changes if indicated.

The Task Force on Preparation for the Teaching of Engineering found that although engineering education has been remarkably successful since World War II, there are some serious problems that require attention, principally in connection with the competitiveness of the United States in international markets. The Task Force believes that engineering is only one element—although a crucial one—relating to this problem. It believes engineering education can contribute to the strengthening of U.S. competitiveness by a greater educational emphasis on the totality of the process of developing and manufacturing high-quality, low-cost products. In particular, the Task Force feels it is wrong to emphasize only the "manufacturing" end of this process and recommends instead that the entire scope of the manufacturing process be enhanced in its visibility, and that research be seen as an integral first step in that process.

In examining the preparation of engineering professors, the Task Force found it necessary to back up and ask what it is that professors are expected to do. It was then necessary to back up another step and ask what it is that the professors' principal products—the graduates—are expected to do. Taking these in reverse order the Task Force's conclusions are summarized as follows.

Conclusions and Recommendations

Expectations

Most employers prefer that their graduates have a solid background in fundamentals, coupled with a certain level of skill in solving problems that have a real-world flavor. It is generally acknowledged that today's graduates have a good preparation in the basics but not as good a background in solving problems, principally because of recent heavy increases in student/faculty ratios but also because faculty members frequently lack direct experience in industry or other engineering practice.

With respect to faculty activities, these are generally grouped under the following headings: 1) teaching, 2) research or other creative activity, and 3) university and community service. The Task Force notes that different educational institutions will differ in their emphasis on these components, but that *teaching* is a special kind of function that distinguishes a university from, say, a research institute. Teaching is thus a primary function in a university or college, and effective teaching should be an essential criterion in appointment or advancement.

Teaching and Research

In a university with strong graduate programs, particularly at the doctoral level, effective performance in research will be held to be equal in importance to teaching, although universities usually make allowance for "engineering design" in this category, provided the designs are conceptually advanced and have significant impact on the field. Institutions with major doctoral programs will probably choose to emphasize published research papers as the principal evidence of creative activity, other institutions may include research as one form of creativity, but de-emphasize its importance with respect to other kinds of activity.

In the case of schools without doctoral programs, there would seem to be little reason to emphasize research as the principal form of creative activity, and a preference would exist for a broad mix of ways in which faculty creativity might be demonstrated. In this category, also, would be schools that offer bachelor's degrees and associate degrees in engineering technology, where forms of creativity other than research may actually be preferred.

Number of Doctorate-Granting Institutions

There were 149 universities offering doctoral programs in the United States in 1983. One-third of these schools produced more than three-fourths of the doctoral degrees. These schools are thus the principal sources of engineering faculty. Nearly half of the doctorate-granting schools awarded fewer than 10 doctorates each in 1983. Our existing system of engineering graduate schools is thus capable of expanding its production to meet any foreseeable need for engineering faculty, and the startup of additional Ph.D. programs is not encouraged.

Ph.D. Requirement for Faculty

At universities that emphasize research and graduate study, the great majority of the engineering faculty should possess doctoral degrees, although it is reasonable that some faculty with unusual accomplishments might be appropriately employed even if they do not hold the doctorate. Extensive industrial experience might in some cases substitute for possession of the Ph.D. In colleges and universities that emphasize undergraduate study, such strong reliance on the doctorate should not be necessary, particularly if the institution itself does not offer a doctoral degree. Greater reliance may then be placed on other forms of accomplishment such as industrial experience, although it seems appropriate for a large share of the faculty to possess doctorates. For institutions offering engineering technology programs at the bachelor's and associate degree levels, the Ph.D. is not a justifiable requirement for faculty status.

Teaching Assistants

There has been much concern that our system does not encourage enough of our best students to seek careers in education. Further, about 44 percent of all engineering teaching assistants are foreign nationals, many of whom are reported to have inadequate English skills. Accordingly, the Task Force recommends that the following steps be taken to improve the quality of those who are attracted into teaching asistant positions, and thus to improve the future quality of the engineering faculty.

- Universities and colleges need to take steps to make engineering faculty positions more attractive and prestigious in order that more of our best-qualified U.S. students will wish to enter a system that leads to a faculty appointment.
- Universities need to make graduate teaching assistant positions more attractive by providing a professional working environment for T.A.'s. This might include providing recognition for outstanding T.A.'s, providing suitable office space, equipment and support, and providing computer services. Stipends for teaching assistants should be increased to a level of at least half the current starting salaries of B.S.-level engineers.

> "Teaching assistants for
> whom English is a second language
> should be required to pass
> the ETS Test of Spoken English
> at an acceptably high level."

- Since experience as a teaching assistant is virtually the only training that prospective faculty members receive for their future careers, the experience should be treated as a more structured learning experience than now seems to be the case. Specific orientation courses should be devised for new T.A.'s, and their activities should be supervised by experienced faculty members, with opportunities for feedback and evaluation.
- Teaching assistants for whom English is a second language should be required to pass the Test of Spoken English administered by the Educational Testing Service, at an acceptably high level. A score of 250 (out of 300) is recommended as a minimum pass level.

Relevance

An aspect of engineering education that receives too little attention in today's crowded curricula is that which imparts an understanding of the international, product-oriented climate in which modern engineers must operate. These include such factors as: satisfying the customer; designing for quality, reliability, safety, cost and manufacturability; satisfying societal needs such as conserving scarce resources and preserving the environment; effective communication, ethical action. Faculty must pass on to their students the problems and limitations of real life. An immersion in meaningful industrial problems will give engineering faculty this additional orientation, supplementing their valuable knowledge of engineering science. We recommend:

- Engineering schools of all types should seek to employ the highest percentage possible of faculty with industrial experience. This applies to research universities as well as others. With the increasing tendency of industry to lead academia in some research fields, and with the increasing tendency for industry to employ engineers with graduate degrees, the need for close relationships between industry and academia becomes stronger than ever.

> "For institutions offering engineering technology programs at the bachelor's and associate degree levels, the Ph.D. is not a justifiable requirement for faculty status."

Specifically, we recommend that all engineering faculty be expected to have accumulated at least two years of experience in industry or in private practice. This experience may be gained through a series of summer jobs, through consulting, by supervising industrially-sponsored research contracts, or some combination of these. It need not all consist of pre-employment experience, but might mutually be understood to be achieved before the granting of tenure. Familiarity with industry should be kept current through consulting, summer employment and joint industry/university research programs.

- Cooperative education programs have great educational value for students because they help provide motivation and direction. They should be expanded to the greatest possible degree, while maintaining high quality. To be of maximum value, they need to be sustained through good times and bad, and not be allowed to wax and wane with economic cycles.

Competent Teaching

Engineering professors must not only be competent technically but must also be effective teachers.

- All persons preparing to teach engineering (the pretenure years) should be required to include in their preparation studies relating to the practice of teaching. It should be the responsibility of the hiring institution to provide guidance and assistance in this aspect of faculty preparation by recommending and sponsoring appropriate seminars, workshops and institutes.
- As a minimum, educational institutions should offer a pre-service workshop or seminar for new faculty members, perhaps involving one week for which extra pay is given, to cover such things as institutional goals and expectations, course organization and development, examinations and grading, student performance, student/teacher interactions and the like. Annual professional development reviews with academic administrators should include discussion of the candidate's progress and growth in teaching.

Reaching Women and Minorities

To achieve the goal of increasing the proportion of women and under-represented minorities on engineering faculties, efforts must be applied across the board, and especially at the high school and junior high school levels, to reduce the effects of economic, educational and cultural factors that now turn members of such groups away from engineering. Major efforts are needed with respect to minority groups at the precollege years, and upgraded retention programs are needed at the college level. Efforts must be made to eliminate discrimination, real or perceived.

Task Force on Preparation for the Teaching of Engineering

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QEEP
Quality of Engineering Education Project

Continuing Professional Development of Engineering Faculty

Task Force Chairman: Robert M. Anderson

Charge: To study the present system of faculty development in the engineering colleges of the nation and to recommend ways the colleges can develop a systematic approach to ensuring technical and pedagogical currency of each faculty member throughout his or her career.

The extremely rapid rate of change in the knowledge base for engineering education makes the engineering educator's task of keeping up to date more difficult than ever. The Task Force on Continuing Professional Development of Engineering Faculty was charged with the responsibility for examining the problem and developing recommendations for action.

Continuing professional development is a process by which professionals enhance their competence in their profession. To address the professional development of engineering faculty, the Task Force begins with an examination of faculty responsibilities. Next it identifies critical issues that demonstrate how continuing professional development is an important problem for engineering faculty members, one that requires special attention and the dedication of significant resources. An examination of current approaches to engineering faculty development reveals their inadequacy to meet today's needs. The Task Force offers a vision of an effective system and identifies groups that have primary, secondary and supportive responsibility for that system. Finally, it offers specific action-oriented recommendations to each group.

Responsibilities of Engineering Faculty

The Task Force has defined three broad areas of faculty responsibility:

1) The creation and acquisition of knowledge,

2) The dissemination of knowledge, and

3) Professional and public service,

and examines them in detail. The resulting picture is that of a complex situation in which the faculty member is expected to be at the cutting edge of a technical specialty, knowledgeable about related specialties and able to change fields as appropriate, and an effective classroom teacher conversant with the best in pedagogy—all while being actively involved in professional and public service.

This examination of responsibilities and expectations points up the difficulties faced by engineering faculty members who wish to stay current in their many-faceted jobs. A question that may be logically posed, however, is: What is critical about the situation today as opposed to any time in the past?

In answer to the question two critical issues are identified which threaten the continuing competence of engineering faculty and put at risk the continuing supply of top-quality engineering graduates to meet the nation's needs. These two issues are a galloping rate of technological change and a parallel demand that faculty review seriously the educational processes used to produce engineers. The Task Force has concluded that in today's world the continuing professional development of engineering faculty cannot be left to chance.

Current Approaches and Effective Faculty Development

A critical review of the current situation with regard to faculty development in engineering schools has yielded a catalog of activities through which faculty pursue continuing professional development. The Task Force concludes that in most institutions faculty development is pursued on an ad hoc basis with little or no purposeful planning.

It further concludes that the primary missing ingredient in our reaching the goal of providing each faculty member the opportunity to stay current is a deliberate professional development plan for each engineering college. Such a plan includes not only the types of activity in which faculty members will engage but also an assessment of the resources needed to support that activity.

> "The primary missing ingredient is a deliberate professional development plan for each engineering college."

Although the fraction of the engineering college budget required for an effective faculty development plan will vary considerably among institutions, each school should begin now to ensure that appropriate resources are regularly allocated to support faculty development activities. If significant amounts of time and money are to be allocated, we can no longer tolerate an undisciplined, ad hoc approach. Purposeful planning by both individuals and institutions is in order.

Responsibilities and Recommendations

Responsibility for engineering faculty development is divided into two major parts. The following have *primary* responsibilities.

Individual Engineering Faculty Members

Faculty members must be primarily responsible for maintaining their own professional competence. Only they know what skills and knowledge they lack. They must have the professional pride and commitment necessary to keeping professionally competent.

- The most important recommendation is that individual engineering faculty members assume primary responsibility for managing their own professional development and that they actively plan and execute their own program.

Engineering College Administration

The college administration bears the responsibility for providing the supportive framework within which each faculty member can be expected to carry out a regular program of continuing professional development. Individual faculty members cannot discharge their primary responsibility without adequate institutional support. An investment of money and attention in professional development should make faculty recruitment easier and should improve teaching and research, which in turn will attract better students and more public and private funding.

- Deans and department chairmen must take the lead in developing and implementing a program for the college under which continuing professional development is a regular part of each faculty member's job. This commitment includes developing the necessary budgetary resources.

University Central Administration

The university administration must also be proactive in recognizing the special resource needs of a good engineering program. In the current climate of increased university/industry partnership it is important that engineering programs, which are of special interest to industry, be maintained at a high level of quality.

- The president and chief academic officer of the university should provide the budgetary support required by the engineering college for an ongoing program of faculty professional development. They must recognize that the engineering disciplines have a particularly fast-changing knowledge base and that engineering faculty need extra institutional support to maintain their competence.

Many groups have a strong interest in maintaining the professional competence of the engineering faculty. Rather than having a primary responsibility to act directly, the following groups have a *secondary* responsibility for aiding and supporting both individual faculty members and their institutions.

Government

Government at all levels has a stake in ensuring that the engineering faculty—the group largely responsible for the competence of the engineering workforce—maintains its own competence. Not only is government a major employer of engineers, but both regional and national governments are responsible for promoting economic growth; the effect on that growth of well-educated engineers and strong engineering colleges is well documented. And only a highly competent engineering faculty can perform the fundamental engineering research so essential to society's future.

- To help engineering faculty and administrators develop comprehensive, ongoing plans of professional development for every faculty member, the National Science Foundation should fund several experiments in the design and implementation of such plans. If undertaken in a variety of institutions, these experiments could produce models on which all types of institutions can draw.
- As an employer, government at all levels should assume a leading role increasing opportunities for meaningful summer and sabbatical assignments for faculty.
- The federal government should ensure that the income tax exclusion now provided for employees who receive tuition support from their employers is not lost. Without the exclusion, a faculty member could be penalized for pursuing some forms of professional development.

Professional Societies

Engineering and professional societies have the charter to preserve and advance the state-of-the-art in specific disciplines. As important contributors to that process, engineering faculty value the common forum that professional society meetings provide to professors and practitioners.

- Professional societies should offer regular, tutorial, state-of-the-art courses specifically for engineering faculty members in conjunction with more traditional society meetings and during the summer.
- Professional societies should also develop "matchmaking" programs to help professors find appropriate developmental employment in their discipline during summers and for sabbatical leaves.

Employers of Engineers

Employers depend on being able to hire capable new engineering graduates and on keeping their workforce technologically current. A capable faculty is necessary to produce capable graduates and can help to keep the existing workforce up to date.

- Employer organizations should make a special effort to provide developmental work assignments to engineering faculty during summer and sabbatical leaves. Industry can make some of its specialized facilities—and employees—available to students and faculty to help both gain experience and competence with modern engineering equipment.

Accreditation Board for Engineering and Technology (ABET)

ABET is constituted to promote and advance engineering education to further the public welfare. Through the accreditation process, ABET exerts considerable influence on U.S. engineering education.

> "Each school should begin
> now to ensure that appropriate
> resources are regularly
> allocated to support faculty
> development activities."

- A thorough review by ABET of accreditation criteria as they relate to faculty competence and development is in order. Although current criteria list a variety of factors by which faculty competence may be judged, the extent to which that judgment is made in practice is subjective and not well understood. Current criteria say almost nothing about faculty members keeping up with new developments. ABET's Engineering Accreditation Committee should undertake to write more quantitative standards for faculty development activities and to use the expanded criteria in their accreditation processes (e.g., self-study, visits, reports). If this change were made, within a decade significant progress in faculty development could be felt in every U.S. engineering program.

Task Force on Continuing Professional Development

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QEEP
Quality of Engineering Education Project

The Use of Educational Technology

Task Force Chairman: Russel C. Jones

The Task Force on the Use of Educational Technology has undertaken a study of the driving forces behind the use of educational technology, previous efforts in applying educational technology, current major issues from a variety of perspectives, and the current technology base available for use.

Driving Forces and Previous Studies

Of the many changes in engineering practice in recent decades, the most dramatic has probably been the introduction of the electronic computer. The rapid rate of technological change and greatly enhanced communications also strongly affect the way engineering students should be prepared for practice. In an effort to make the educational process more effective, and in particular more cost-effective, simulation is seen as an alternative to costly laboratory equipment. The need to make continuing education more accessible further encourages the use of educational technology.

In reviewing previous studies and how various technologies have been applied to engineering education and related fields, the Task Force hopes to provide objective evaluations and a background from which engineering schools can consider currently available technologies.

Charge: To identify the technology now available for potential use in improving the efficiency and currency of engineering education, to study the problems and promise of experiments underway in engineering colleges in the use of such technology, and to recommend a viable approach toward integrating appropriate technology into the engineering education process of the nation over the next decade.

Major Issues and Current Technology

The problems and promise associated with the use of educational technology are being explored through an examination of the major issues related to students, faculty, graduates, curriculum and logistics. Among the items under study are:

- How to define computer literacy for the engineering graduate;
- The slow pace at which curricula change to incorporate new technology;
- How extensively advanced technologies are being used in upper-division courses;
- The need to develop an appropriate reward system for faculty involved in developing and using educational technology;
- Distributed delivery of continuing engineering education;
- Portability of software and courseware; and
- Institutional costs of using educational technology.

A review of the current state-of-the-art and future directions of four technologies—computers, video, print and communications—makes clear that engineering educators must act now to prepare for the academic environment they desire in the decades ahead.

Goals and Recommendations

In response to the charge of the Task Force, it seems appropriate to [illegible] first a set of overall goals for the desired impact of educational technology in engineerng education, then to develop a set of specific recommendations on how to meet those goals.

The following are the overall *goals* proposed by the Task Force:

- The links between practice and education need to be substantially strengthened.
- Engineering education must be a lifelong process in order to keep graduates current once out in practice.
- Engineering curricula need more design content, in general, and correspondingly less detailed coverage of analysis.
- Engineering faculty (not just education faculty) need to work toward educational enhancement.
- The effectiveness and efficiency of engineering education must be improved.
- The diversity of experiences available to students needs to be increased, in order to broaden and deepen the educational experience.
- Continued faculty growth and development must be nurtured.
- Mechanisms to develop and distribute software and courseware, parallel to those available in the textbook field, need to be established.
- Hardware, software and courseware must be standardized to allow portability among academic units.

These goals can be fleshed out through the examination of specific *recommendations* to each of several constituencies in engineering education. The following subsections list recommendations for such groups.

Engineering Faculty

Engineering faculty members, individually and collectively, should take the following actions:

- Take leadership roles on campus in developing and applying appropriate educational technologies.
- Share software and courseware freely both on campus and throughout engineering education, minimizing intellectual property rights barriers.
- Work with university administrations to develop appropriate intellectual property rights policies and procedures, with equitable reward structures for both faculty members and universities, while keeping the products affordable to the consumer.
- Be innovative in updating the engineering curriculum to use the latest technologies effectively.
- Get involved in the off-campus delivery of continuing education, using educational technology as appropriate.
- Assist in developing methodologies for advanced educational delivery systems.
- Place a high priority on developing and using modern instructional methods and using educational technology to prepare engineering students adequately in design.

University Administration

The administrations of universities with engineering schools should:

- Develop strategic plans for necessary and appropriate allocation of resources to develop educational technologies (perhaps on the same order of magnitude as currently allocated to the library system).

> "The administration should recognize and reward faculty members who develop software, courseware and systems to allow appropriate and effective use of educational technologies."

- Recognize and reward faculty members who develop software, courseware and systems to allow appropriate and effective use of educational technologies—including the ultimate rewards of promotion, salary raises and tenure.
- Develop mechanisms for the *distributed* funding of developments in educational technology, recognizing that the traditional centrally-funded academic computing center seldom provides a hospitable locus for such activities.
- Provide stimuli to promote the upgrading of faculty members in the use of modern educational technology (training, sabbatical opportunities, seed funds, etc.).
- Work with faculty to develop procedures whereby those who develop software and courseware can equitably share in the financial returns they generate.

Technology Vendors

The manufacturers of advanced delivery products intended for use in engineering education should:

- Strive to deliver more capability and higher quality products, at the lowest possible prices and requiring as little maintenance as possible.
- Move rapidly toward industry-wide standardization of hardware and operating systems.
- Develop reasonable cost approaches to site licensing on campus.

- Make equipment grants (with support services) to engineering schools willing to use advanced delivery systems and develop courseware for them—including schools that have not traditionally been leaders in such use.

"Technology vendors should move rapidly toward industry-wide standardization of hardware and operating systems."

- Provide exchange programs for faculty members and corporate leaders, including sabbaticals in both directions, for those interested in educational technology.
- Develop educational efforts to bring engineering faculty members up to speed in the use of advanced educational technologies.

Accreditation and Professional Societies

The several engineering societies concerned with engineering education in their particular technical fields, the Accreditation Board for Engineering and Technology, and the American Society for Engineering Education should:

- Ensure that engineering students are adequately exposed to the use of appropriate educational technologies, both to provide better initial engineering education and to promote more effective use of such technologies in lifelong learning.
- Give appropriate coverage to developments in educational technologies in society publications, seminars and conferences, and award programs.
- Develop and promulgate appropriate accreditation standards concerning desirable use of such technologies in engineering education.

Government Bodies

The several government bodies concerned with engineering education, including the National Science Foundation and the federal mission-oriented agencies, should:

- Take a leading role in promoting the appropriate development and use of educational technologies, through attractive funding programs.
- Promote the establishment of tax credits and other incentives for equipment contributions and the funding of research and development in the educational technology area.
- Provide mechanisms for the dissemination of results of educational technology research (publications, conferences, short courses, etc.).
- In collaboration with state agencies, provide funding sources to develop educational technology systems throughout U.S. engineering schools.

Corporate Employers

Those organizations that employ graduate engineers, and rely on engineering schools to assist in their continuing education, should:

- Take positive steps to promote and support the use of appropriate educational technologies in both the original engineering education and in lifelong learning.
- Insist that engineering schools graduate students adequately prepared to work in design and/or manufacturing in the modern computationally-oriented world of practice.
- Assist schools in obtaining modern technologically-oriented equipment for classrooms and laboratories.

Task Force on Use of Educational Technology

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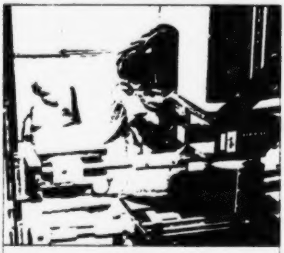
QEEP
Quality of Engineering Education Project

The Undergraduate Engineering Laboratory

Task Force Chairman: Edward W. Ernst

As part of its efforts, the Task Force on the Undergraduate Engineering Laboratory distributed questionnaires asking for information and opinions related to the laboratory-oriented portions of engineering and engineering technology programs. These questionnaires were distributed to selected academic institutions that offer programs in engineering and engineering technology, industrial organizations that employ graduates of these programs, and engineering professional societies. The responses have corroborated the Task Force's understanding in some cases and offered new insights in others. In general, the responses demonstrate a significant interest in engineering laboratory studies in both academia and industry.



Charge: To study the current role of laboratory instruction in engineering education, to assess its future role, and to develop recommendations on means for ensuring the full partnership of laboratory instruction in the engineering education process.

This interim report is divided into findings and recommendations.

Findings

These statements about the undergraduate engineering laboratory are drawn from the deliberations of the Task Force and the responses to the questionnaire.

Educational Value

1) The laboratory segment is a valuable part of an engineering or engineering technology education. This view comes from those in academic institutions *and* those in industry. For some, laboratory experience is *the* facet that sets these programs apart from other educational programs at the same academic levels.

Objectives

2) Although many functions and roles for the undergraduate engineering laboratory are described, the primary objectives for the laboratory portion of an engineering education may be stated as:

a) The student should learn to do experimental work. This includes planning the experimental work, conducting the experiment and analyzing the results.

b) Laboratory work should serve to reinforce the concepts presented in other parts of the educational program. The impact on the student of observing the physical phenomena described in texts and other literature, as well as that presented in lectures, is significant and enhances the learning process.

c) The laboratory portion of the program provides an opportunity to develop the student's ability to communicate effectively. Although many parts of the engineering program may provide opportunities to develop communication skills, the laboratory is believed to provide an opportunity that is more appropriate than most for developing the kinds of communication skills required in engineering practice. The experiments conducted by students constitute engineering information that the student has participated in creating; communication of this information to others requires skills similar to those needed by engineers in communicating results of engineering work to supervisors or other interested parties.

The questionnaires indicate that objective (a) is clearly accepted by all groups as a primary objective. Objective (b) appears to be secondary for those in academia, while objective (c) is clearly secondary for those in industry.

3) Although the competence of recent graduates for experimental tasks appears acceptable, further on-the-job training is required. In general, the associate degree and baccalaureate engineering technology graduates appear better prepared for the experimental tasks expected of them than do graduates of engineering programs. Some graduates of baccalaureate engineering programs require considerable added training before they can undertake the experimental work expected of them.

4) The associate degree engineering technology graduates are expected to have experimental capability that extends beyond the particular disciplinary specialty to a greater degree than do graduates at the baccalaureate level. However, there appears to be a universal need for engineering graduates in all disciplines to have experimental competence that includes electronics and the use of the computer for experimental work.

5) There are two primary obstacles to excellent undergraduate engineering laboratory programs. The one mentioned most frequently is the lack of appropriate kinds and adequate amounts of equipment. Included here is the lack of adequate resources for maintaining equipment and the lack of adequate, appropriately-equipped space for instructional laboratories. The second obstacle is the lack of participation in laboratory instruction by engineering faculty. The relatively low level of faculty involvement appears to result from the lack of recognition and reward for such faculty efforts.

6) Although nontraditional approaches to laboratory instruction are considered by many to be valuable ways for strengthening the program of laboratory instruction, there appears to be little, if any, support for replacing traditional hands-on laboratory experience with other approaches.

Recommendations

Encouraging Cooperation with Industry and Government

- The value of laboratory-oriented instruction as an essential part of an engineering or engineering technology education must continue to be affirmed by industry and the engineering societies, as well as the academic institutions offering programs in engineering and engineering technology. This affirmation must be expressed in the curriculum, in the allocation of resources and the in the faculty reward system. Industry must make more clear to faculty, administrators and students its interest in and concern for an excellent laboratory program.
- Engineering colleges should take the initiative to establish vehicles for interaction with industry that focus specifically on the mutual need for excellence in laboratory instruction and that provide a forum for identifying ways in which each can contribute to overcoming barriers to excellence.
- Significantly increased levels of support are needed for new laboratory equipment, the ongoing maintenance of the equipment and its replacement. In addition to the usual institutional sources of funding, other sources, including federal and state grants and gifts from industry, must be explored to provide the continuity of resources needed to prevent a recurrence of the current equipment-obsolescence crisis. More attention is required on the part of both academic institutions and industry to ensure that equipment donated by industry is appropriate and effective in improving the quality of the undergraduate laboratory experience.
- Active and vigorous representation to institutional governing and funding bodies on the part of industry and other employer organizations is required to encourage adequate funding of the undergraduate laboratory program.
- The federal government should support, through the National Science Foundation, the development of innovative approaches to laboratory-oriented studies for engineering students. These could include the use of simulation, computer-aided measurement and experi-

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mentation, and the use of modern educational technology.

Industry Experience for Faculty and Students

- Industry should provide internship opportunities for faculty to learn about current industrial laboratory practice. Adjunct faculty from industry can bring industry experience to the laboratory for both direct instruction and course development.
- Industrial organizations are encouraged to work with academic institutions to provide more opportunities for co-op and summer internship experiences that will enhance and supplement students' on-campus laboratory experiences.

Faculty Support and Recognition

- The time required of faculty to teach laboratory courses should not be significantly greater per teaching-credit-hour than that expected for teaching in other modes. Although this recommendation is primarily directed to academic institutions, support from industry and professional societies through the Accreditation Board for Engineering and Technology is needed to encourage faculty participation in laboratory instruction.
- Greater consideration should be given to the use of adequate numbers of qualified personnel to support faculty in laboratory instruction. These support persons include technicians and academic professionals.
- The requirements for faculty promotion and tenure should encourage young faculty members to participate in laboratory instruction. Faculty members who demonstrate unusual competence and ability in such instruction should be recognized and rewarded to the same extent as those whose competence lies in other areas.

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March 12, 1986

The Honorable Doug Walgren
House Subcommittee on Science, Research and Technology
2319 Rayburn House Office Building
Washington, D.C. 20515

Dear Mr. Walgren,

The Society for American Archaeology would like to express support for the Administration's budget for the National Science Foundation. The National Science Foundation has played a crucial role in archaeological research and development, and has made a great impact in both public and academic domains.

Currently, major opportunities have arisen in basic archaeological research. As a result of federal archaeological preservation legislation, an extensive collection of data has been generated by contract archaeological surveys and excavations.

The National Science Foundation is in a unique position to access and utilize this raw data, enabling development of long overdue regional integration studies. A regionally integrated study of this nature will foster the discovery of long forgotten prehistoric plants and resources which have contemporary practical applications. For example obsidian glass (used for a variety of prehistoric tools), today is being considered as a surgical scalpel. Obsidian surgical incisions promote a rate of post surgical recovery time which is half that of contemporary surgical scalpel incisions. Obsidian surgical incisions promote a rate of post-surgical recovery time half that of contemporary surgical scalpel incisions. Furthermore, archaeological evidence has led to the rediscovery of two long forgotten prehistoric plants. These seed bearing plants, Amaranth and Chenopodium both provide a source of complete protein as well as high levels of calcium, iron and other essential vitamins, offering a valuable worldwide food source.

The Administration's National Science Foundation budget proposal for fiscal year 1987 will allow increases in archaeological research and development, increases which are critical for establishment of regional intergration studies that provide invaluable potential for rediscovery of numerous raw resources.

SOCIETY FOR AMERICAN ARCHAEOLOGY

The Society for American Archaeology would like to request the inclusion of language in the 1987 National Science Foundation appropriations to highlight the importance of archaeology and the opportunities in archaeology at the Foundation.

Thank you for your consideration.

Sincerely,

Philip Speser, J.D., Ph.D.
Washington Representative
Society for American Archaeology